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GEOLOGICAL MAGAZINE

VOL. LXXXVI. No. 1. JANUARY-FEBRUARY, 1949

International Geological Congress

Eighteenth Session—Great Britain, 1948

ABSTRACT

The scientific proceedings of the Eighteenth Session of the International Geological Congress included twelve series of Sectional Meetings, open meetings of the Association of African Geological Surveys, and of the International Paleontological Union, and special discussions on the Geology and Mineralogy of Clays. Summaries of these Sectional and other meetings, prepared by their officers, are published in advance in the full Report of the Session.

PROCEEDINGS OF THE SECTIONAL MEETINGS

Introduction

By A. J. BUTLER

TWELVE separate series of Sectional Meetings were arranged during the Eighteenth Session :—

Section.	*First Chairman.*	*Secretary.*
A. Problems of Geochemistry	C. E. Tilley	S. R. Nockolds
B. Metasomatic Processes in Metamorphism	A. Holmes	Doris Reynolds
C. Rhythm in Sedimentation	W. G. Fearnsides	P. Allen
D. The Geological Results of Applied Geophysics	W. F. P. McLintock	J. McG. Bruckshaw
E. The Geology of Petroleum	V. C. Illing	G. D. Hobson
F. The Geology, Paragenesis and Reserves of the Ores of Lead and Zinc	W. R. Jones	K. C. Dunham
G. The Geology of Sea and Ocean Floors	O. T. Jones	W. B. Harland
H. The Pliocene-Pleistocene Boundary	W. B. R. King	K. P. Oakley
J. Faunal and Floral Facies and Zonal Correlation	A. E. Trueman	H. Dighton Thomas
K. The Correlation of Continental Vertebrate-bearing Rocks	D. M. S. Watson	W. E. Swinton
L. Earth Movements and Organic Evolution	H. L. Hawkins	F. Hodson
M. Other Subjects	E. B. Bailey	R. M. Shackleton

The Chairman opened the proceedings of his Section, and was afterwards at liberty to invite other geologists to succeed him in the

Chair. The Secretary recorded the whole of the proceedings of the Section.

In addition to the Sectional Meetings proper there were three other series of open meetings, arranged by :—

The Association of African Geological Surveys : President, F. Dixey ; Secretary, F. Blondel.

The International Paleontological Union : President, P. E. Pruvost ; Secretary, B. F. Howell ; Secretary of the British Committee, C. J. Stubblefield.

The Clay Minerals Group of the Mineralogical Society : Chairman, G. W. Brindley ; Secretary, D. M. C. MacEwan.

The following pages contain summaries of these Sectional and other meetings, prepared by their officers. The country of each contributor from abroad is given in brackets after the first mention of his name ; except in the cases of the Chairmen, personal titles are omitted.

An account of the general proceedings of the Session and of the main conclusions of the Council was given in the last number of the *Geological Magazine* (A. J. Butler, *Geol. Mag.*, 1948, lxxxv, No. 6, 361–5).

Section A: Problems of Geochemistry

By S. R. Nockolds

There were three meetings of Section A, Problems of Geochemistry, during the course of the Congress. The first of these opened with Professor C. E. Tilley in the Chair, and he was succeeded half-way through by Professor P. Niggli (Switzerland).

The first paper was one by N. L. Bowen (U.S.A.) and O. F. Tuttle (U.S.A.), on " Serpentine and talc equilibria ", and gave the results of experimental investigations of the equilibrium relations of talc and serpentine with the anhydrous phases forsterite, enstatite, periclase, and silica, at pressures of water vapour up to 30,000 pounds per square inch and temperatures up to 900° C. No liquid phase is formed in any composition up to the highest temperatures and pressures at which the investigations were carried out. The following paper by J. M. C. Neiva (Portugal), on "Serpentines and serpentinization ", outlined a detailed classification of the essential serpentinous minerals, and the author suggested the possibility of explaining hypogene serpentinization in the solid condition by the diffusion of H^+ ions through the crystal lattices during the final stages of differentiation of the peridotitic magma.

H. von Eckermann (Sweden) dealt with " The distribution of barium

in the alkaline rocks and fenites of Alnö Island ". The data available show that there was considerable migration of Ba ions from the intrusive liquids into the metasomatically altered wall rock, and that Ba is concentrated in the residual solutions as exemplified by the leucocratic and carbonatitic rocks rich in potash.

A paper which gave rise to considerable discussion was that by E. Saether (Norway), " On the genesis of peralkaline rock provinces ". The author holds the view that peralkaline magmas are generated by diffusion processes in a magma mass of very great vertical extension. In such a mass, the volatiles and ions such as Na^+, K^+, Ca^{++}, Ba^{++} will be enriched at the top of the chamber and hence a peralkaline magma, rich in CO_2 and other volatiles, will be formed.

C. Oftedahl (Norway) considered " Special features of the Oslo igneous feldspars ". Detailed investigation shows that plagioclase, previously unidentified owing to the fact that the albite lamellae are exceptionally thin and can be seen only in sections perpendicular to (010), forms an important constituent of such rocks as larvikite, lardalite, and some nordmarkites. The alkali feldspars are transitional from cryptoperthite to microperthite and the cryptoperthites were found to belong to the " orthoclase-microperthite series " of Ed. Spencer.

The final paper was one by E. S. Larsen (U.S.A.) and W. M. Draisin (U.S.A.), " Composition of the minerals in the rocks of the Southern California batholith." The batholith contains rocks ranging from calcic gabbro to granite and nearly all the analyses lie near smooth variation curves, indicating a close consanguinity. It was found that the ratio $\frac{FeO}{FeO + MgO}$ is about the same for any rock and for all the mafic minerals in that rock, and increases along a smooth curve from 0·36 in the calcic gabbros to 0·85 in the granites. The anorthite content of the plagioclase changes regularly with the composition of the rock. The minerals of these coarse-grained rocks were compared with the phenocrysts of the volcanic rocks of the San Juan region of Colorado, where no such systematic changes occur.

Dr. N. L. Bowen was in the Chair for the first half of the second meeting and was followed by Professor W. Wahl (Finland). P. Niggli opened the proceedings with a paper on " The presentation of geochemical data ". After dealing with the various methods of presentation and pointing out that a certain uniformity was desirable, the author gave examples of the advantages of using atomic and molecular values, rather than weight-percentage values.

W. Nieuwenkamp (Netherlands), in a paper entitled " The geochemistry of sodium ", considered certain aspects of the geochemistry of that metal from a quantitative point of view, while R. W. van

Bemmelen (Netherlands), in " Cosmogony and geochemistry ", attempted to describe geological evolution as a link in cosmic evolution. In stellar evolution the course of the process is determined by nuclear reactions ; in the development of planets the reactions between the outer electronic shells play a dominant role. Deductive reasoning about the origin of the planetary system leads to conclusions about the character and course of the endogenic process. The source of endogenic forces is the energy liberated by irreversible, physico-chemical chain-reactions.

In a paper " On geochemical types of orogenic zones ", Y. A. Bilibin (U.S.S.R.) distinguished internal and external zones of metallogenic belts. The internal zones are characterized by metals of the Fe group, the Pt group, Cu, Mo, Hg. The external zones are characterized by Sn, W, Bi, Pb, Zn. The two zones differ also in the nature of their mineralizers and in their rock types.

D. S. Korzhinsky (U.S.S.R.), dealing with " Phase rule and geochemical mobility of elements ", showed that by applying the phase rule to rocks it could be established that some components under given conditions are " perfectly mobile " (their concentrations in solution being independent factors), whereas others are " inert " (their concentrations in solution being functions of their content in the rock). The geochemical mobility of elements and oxides depends on the activity of solutions, temperature, and depth, and three series of decreasing mobility were given, (*a*) for high temperature processes at depth, (*b*) for high temperature processes near the surface, (*c*) for low temperature processes near the surface.

Finally, J. P. Marble (U.S.A.), gave a paper on " Some applications of autoradiography ", in which he showed that a prepared surface of a radioactive mineral, when placed in direct contact with a photographic plate for an optimum time, will yield valuable information as to the relative radioactive content of different parts of the specimen. Moreover, by exposing for the same length of time chips of an unknown mineral with others whose U + Th content is known, a semi-quantitative estimate of the U + Th content of the unknown can be rapidly made.

At the final meeting, Professor P. Geijer (Sweden) and Professor D. S. Korzhinsky occupied the Chair. W. Wahl presented a paper on " The vertical circulation of matter in the earth's crust ", dealing with the vertical circulation brought about by warping down of portions of the crust whereby palingenic granite magma is formed at certain depths by differential remelting of the crust. This magma, being less dense than the remaining femic material of the partially molten rock, will rise and form an upper " sial " layer, the remaining femic material forming the upper portion of the " sima " layer. The sodium-rich

portions of the plagioclase feldspars of diorites and gabbros will also melt at certain depths, together with the kaliophilite constituent of broken up mica, forming foyaitic magma. Where the entire rock ground is remelted, the granodioritic magmas of the orogenic belts are obtained.

L. R. Wager and R. L. Mitchell considered " The distribution of Cr, V, Ni, Co, and Cu during the fractional crystallization of a basic magma ". The amounts of these elements had been determined spectrographically in the rocks of the Skaergaard intrusion and in the plagioclase feldspars, pyroxenes, olivine and iron ore in the rocks.

J. S. Brown (U.S.A.) questioned the validity of the hydrothermal origin of ores in a paper entitled " An alternative to the hydrothermal theory of ore genesis ". Paragenesis is related to specific gravity in such a way as to indicate gravity stratification in the source magma. Zoning is similarly related to volatility and this implies that the major method of transfer was as vapour. Support for the theory is found in the principles of blast furnace smelting with the differentiation of dissimilar substances into layers of slag, matte, and speiss. The heavy sulphide layers were shown to be analogous to probable sulphide ore magmas. An English abstract was given of a paper by C. Andreatta (Italy) " Sull'alterabilità dei minerali delle rocce ", in which he considered some aspects of the alterations of rock-forming minerals, and G. M. Cardoso (Spain), in association with I. P. Pondal (Spain), closed the proceedings with a paper on the chemistry and mineralogy of a porphyritic biotite granite and its associated rock types, entitled " Quimismo de algunos granitos de Pontevedra (España) ".

Section B. Metasomatic Processes in Metamorphism

By Doris L. Reynolds

Professor A. Holmes was Chairman at the opening of the meetings of the Section ; subsequently Professor H. H. Read, Professor E. Wegmann (Switzerland), Professor E. S. Larsen (U.S.A.), Professor P. Eskola (Finland), and Professor H. von Eckermann (Sweden), were invited to the Chair.

Many of the papers presented to Section B, on metasomatic processes in metamorphism, were concerned with the phenomena of granitization, one of the most actively discussed geological topics of the present time. Whereas all the participants were agreed that there is good evidence that various types of rocks have been granitized, there was a sharp division of opinion as to the way in which this has been brought about. Some geologists, adhering to the view advanced by the French school in the last century, considered that metasomatic replacements

resulting in granitization are to be attributed to the action of granite magma, visualized as having been injected along easily penetrable divisional planes within the rocks concerned. The alternative explanation, for which evidence was presented by several geologists, is that granitization is the result of solid diffusion.

P. Eskola considered that the fact that some granites, having all the hall-marks of a metasomatic origin, are identical with others that he regarded as of magmatic origin is strong evidence for the notion that granite magma has been the source of the added materials in all cases. He selected granophyre as a typical granitic rock that he thought all geologists would agree to be of magmatic origin, and pointed out that the metasomatic granites in the Pre-Cambrian of Finland are chemically similar. Eskola then indicated, for common rock types, the constituents that have to be added to bring about granitization, and stressed the fact that other constituents have to be subtracted. Thus, for example, when argillaceous rocks are granitized the chemical change implies addition of SiO_2 and K_2O and subtraction of FeO and MgO. Eskola thought it impossible to say what has become of such displaced constituents, the removal of which he supposed to be controlled by the law of mass action.

In a study of the origin of the Sörmland gneisses of Central Sweden, N. H. Magnusson (Sweden) concluded that leptites, slates, and granites have been transformed to gneiss as a result of introduction of Al, Fe, and Mg, with removal of Si, Ca, and alkalies. He ascribed the change to the action of granitic emanations and solutions derived from deeper levels as a result of palingenesis. In doing so he claimed for granitic solutions an effect diametrically opposed to that which Eskola supposed to obtain.

Doubt was thrown on the magmatic origin of granophyres in general, an assumption that formed Eskola's starting point, by Doris L. Reynolds, who demonstrated with lantern slides the detailed transition of Caledonian granodiorite to Tertiary granophyre on Slieve Gullion, in Co. Armagh, N. Ireland. This transition has clearly taken place in the solid state, the transformation having resulted from introduction of K and Si, with concomitant removal of Fe, Mg, and Ca.

H. G. Backlund (Sweden), in a paper presented *in absentia*, showed that the Swedish granites of Revsund, Filipstad, and Uppsala, all conforming with the chemical criteria generally adopted for the recognition of supposedly magmatic granites, have resulted from solid diffusion. His demonstration, depending on structural, textural, petrographic, and geochemical evidence, leads to the conclusion that the mega-porphyritic granites are the transformation products of sediments of fairly equal competence exhibiting harmonious isoclinal folding, whilst the even-grained granites represent sediments of varying

competence with crumpling and disorderly folding. Consequent on granitization Fe, Mg, etc., were displaced and became fixed within limestones and basaltic rocks intercalated in the geosynclinal sediments undergoing granitization, and in skarn of basic front type. Geochemical investigations have revealed the fact that the trace elements in ores associated with the granites and skarns exhibit highly variable proportions incompatible with any supposition that the ores are a consequence of magmatic differentiation. H. G. Backlund explained the ores as the result of enrichment, at several different periods, of original poorer sedimentary ore deposits. He correlated these enrichments with expulsions of excess materials from sedimentary rocks (probably biochemical) that are now granitized ; on this view the variable proportions of trace elements within the ore minerals reflect the geochemical discontinuities that characterized these sediments.

H. G. Backlund's paper reminded E. S. Larsen of a granite exposed in a tunnel near Ware, Massachusetts. In the tunnel, gently dipping mica-schists are cut by a granite mass over a mile wide. Near the contacts with the granite the schist contains lenses of granite, several inches thick, that extend parallel to the bedding and schistosity. The schistosity has not been distorted and bent as it must have been if the granite had been injected. The granite-schist contact is sharp and cuts across the schistosity, but the granite shows a distinct though faint layering parallel to that of the schists.

E. Wegmann said that from a structural point of view granite massifs are of two types, those formed by transformation *in situ*, and diapirs formed by mobilization. He stressed the fact that intrusion is a displacement, and that study of intrusions is essentially a study of differential mobility for which modern tectonic methods are necessary. Even when movement has been proved, Wegmann said, it then becomes necessary to discriminate between flow of material in a melted condition and flowage of material comparable to that of glacier ice. He further said that Goldschmidt's geochemical work demonstrated the mobility of certain materials, but his results lacked co-ordination with geological events. Careful study of the stratigraphic, tectonic, and kinematic setting reveals the phenomena of transformation in terms of a tectonic geochemistry.

D. S. Korzhinsky (U.S.S.R.) discussed metasomatic diffusion zoning in fissures and metasomatic filtration zoning within rock masses. In principle he considered that diffusion resulting in such zoning could take place either through aqueous pore solutions or through a solid crystalline medium. Study of granite-gneiss contacts, however, especially with reference to reaction zones between adjacent rocks, led him to the conclusion that metasomatic phenomena in

metamorphism occur only in rocks which are soaked by ascending solutions.

M. E. Roubault (France) proposed that, at the next meeting of the International Congress, the study of veins associated with granite should receive particular attention ; if veins have really been filled by magmatic agencies then it should be possible to fit their walls together without leaving any gaps. He said that whereas it is certain that there are granites of metasomatic origin, it is still questionable whether granite of magmatic origin exists or not.

L. T. Nel (S. Africa) exhibited a series of coloured lantern slides of manuscript geological sheets, with the object of drawing the attention of geologists to extensive exposures of granitized rocks in Namaqualand, South Africa. He said that in Namaqualand there are highly metamorphosed sedimentary rocks with associated lavas and dolerites which appear to provide a gradual transition from stratified rocks into gneisses and granite. He thought that this area could provide much evidence of the kind needed for a satisfactory solution of the problem of the origin of granites.

Other important contributions presented to Section B, describing metasomatic phenomena dependent on introduction of materials similar to those lost during granitization, were presented by I. Campbell (U.S.A.) and A. R. Alderman (Australia). Campbell described a series of meta-sediments, possibly including some meta-volcanic rocks, within which a stock-like mass of tonalite has been emplaced. The dominant rock within the meta-sediments is composed of dolomite and brucite, so that it contains too high a ratio of MgO to CaO to be explained as a dolomitic sediment that has recrystallized without change of composition. Obviously, MgO has been added from an external source, and Campbell discussed the various possibilities.

Alderman described some sillimanite and kyanite rocks from Australia that have resulted from alumina metasomatism.

An important paper by H. von Eckermann showed that nepheline-syenite at Alnö, which had previously been thought to represent a magma, is in actual fact nephelinized gneiss. He also demonstrated that carbonate rocks associated with the nepheline-syenite, which have previously been regarded as limestone xenoliths, occupy the cone-sheet fractures of a volcanic breccia.

Section C. Rhythm in Sedimentation

By P. Allen

" Rhythm," as used by geologists in Section C, is a general term describing the repetition of sedimentary types in space or time. The

repetition is observed by measuring vertical sections such as quarry faces, bore-holes, and cliffs, and by detailed mapping. It may be simply *banding* (as 1212121 . . .), or *cyclic* (as 123212321 . . .), or *pulsatory* (as 123, 123, . . .), and intermediate forms of rhythm are known to occur. The discussions were confined to cyclic and pulsatory rhythms, and included rocks ranging from Pre-Cambrian to Recent.

A great variety of possible causes (compaction, subsidence, climatic variation, change in topography and constitution of contributory land-areas, etc.) was debated. As the work of the Section proceeded, it became increasingly clear that (1) the same general types of rhythmic lithology have very wide distributions (e.g. the Upper Carboniferous cycles and pulses of North America and Europe); (2) the underlying causes may vary from place to place and time to time; (3) similar lithological sequences do not necessarily imply similar causes.

The first meeting (Chairmen: Professor W. G. Fearnsides and Professor R. C. Moore (U.S.A.)) was devoted to Palaeozoic cycles and pulses. R. C. Moore, H. R. Wanless (U.S.A.) and B. Willard (U.S.A.) spoke from experience in the United States, S. van der Heide (Netherlands) from experience in Holland and Anatolia, and K. C. Dunham from the northern Pennines of England. The emphasis placed by van der Heide on compaction (with subsidence) as an important factor in causing rhythm stimulated a valuable discussion. A comparison between certain cycles of northern England (Dunham) and those of America (Moore, Wanless, Willard) resulted in an attempt to find agreement over the best stratigraphical level at which the beginning of a cyclothem should be placed. This failed, partly owing to some workers' preferring a rigid genetic classification while others (field geologists) preferred the base of a cyclothem always to be a mappable boundary, and partly because many workers saw no advantage in such standardization anyway.

The second meeting (Chairman: Professor W. G. Fearnsides) was devoted to Mesozoic and Tertiary rhythms. G. Troedsson (Sweden) described the Rhaetic-Liassic beds of Sweden, A. Vatan (France) the Cretaceous and Tertiary sedimentation of the Aquitaine basin, A. Bersier (Switzerland) the mollasse of the alpine fore-deep, and E. Wegmann (Switzerland) discussed the rhythmic effects of climate as opposed to earth-movements.

The contribution of A. Vatan was unique in that it dealt principally with rhythms in detrital composition, and that of A. Bersier stirred up a lively debate. During the latter, A. E. Lombard (Belgium) outlined a new explanation of certain types of cycle and pulse.

Section D. The Geological Results of Applied Geophysics

By J. McG. Bruckshaw

Fifteen papers were presented at the three meetings of this section, each meeting containing papers on related subjects. Appropriately, instruments and new techniques were not covered, the application of standard methods to special geological problems being the main theme. The section was opened by the Chairman, Dr. W. F. P. McLintock, but subsequently the Chair was occupied in succession by Dr. L. Migaux (France), Dr. A. van Weelden (Netherlands), Dr. J. Renner (Hungary), and Dr. J. Phemister.

Four of the papers in the first session, on electrical surveys, were devoted to resistivity surveys. I. de Magnée (Belgium) summarized a successful application which delineated a diamond-bearing pipe in the Belgian Congo, its presence but not its position being known from geological considerations. The important problem of water location was treated by J. J. Breusse (France), and G. Castany (Tunisia). The former was able to distinguish between fresh and saline waters on the Dakar Peninsula, while the latter described the location of buried faults in Tunis, the faults controlling locally the accumulation of water. The last resistivity survey, discussed by L. S. Palmer, was to determine the chalk contours below recent deposits in Holderness, and it illustrated some of the interpretational difficulties arising from the variability of geological formations. In his description of a potential drop ratio survey, A. A. T. Metzger (Finland) suggested a modification of the normal method of plotting the results, a modification which, in the example discussed, appeared to have diagnostic value. Considerable interest was shown in the telluric method discussed by L. Migaux (France), who demonstrated in two cases that this method, coupled with resistivity observations, gave a clearer picture of underground conditions than the gravity method.

The seismic investigations ranged from deductions made from near earthquakes, through normal reflection methods to small-scale studies. F. Montandon (Switzerland) illustrated, in the North-West Alps, the close relation between zones of frequent and intense shocks and regions with numerous and large faults and dislocations, the latter showing previous seismic activity. The fortunate relation between the focus of the earthquake of 25th January, 1946, in Switzerland, and four recording stations, allowed N. Oulianoff (Switzerland) to examine the crustal structure there and to suggest a tectonic relationship between the massifs of Mont Blanc and the Vosges, and those of the Aar and the Black Forest. Seismic reflection methods, used by O. Heermann (Germany) in the N.W. German Permian Basin, have resulted in a better appreciation of the growth and structure of saltdomes there

while, on a still smaller scale, O. Vecchia (Italy) described many successful dam site surveys in Italy, using the refraction technique.

V. E. Barnes (U.S.A.) described the first successful gravity survey leading to the discovery of a lead-zinc deposit. The small anomalies here contrasted with those in Wales and the Borders discussed by H. I. S. Thirlaway, and which showed the lack of isostatic compensation in the Mid-Wales Plateau and the existence of large faults near Worcester. An interesting torsion balance survey over the Warburton Fault, Cheshire, concluded the contributions on this aspect. The two final papers involved the co-ordinated interpretation of several surveys in the same area. The area between the Saone and the Rhone was discussed by J. Goguel (France) in the light of gravity, telluric, and resistivity surveys, while A. Bentz (Germany) described the magnetic, gravity, and seismic refraction maps of N.W. Germany and their geological significance.

The proceedings illustrated the wide range of geological problems amenable to solution by these methods, if due attention is given to the geological conditions, and further revealed a growing tendency to employ them to assist in the elucidation of both academic and commercial problems.

Section E. The Geology of Petroleum

By G. D. Hobson

The three meetings of Section E were conducted under the general Chairmanship of Professor V. C. Illing, but during part of the first Mr. P. Evans occupied the Chair, while Dr. G. M. Lees officiated during the second, and Dr. H. G. Kugler (Trinidad) and Mr. A. R. Denison (U.S.A.) during the last meeting.

The first paper at the Thursday morning meeting was read by L. Barrabé (France). In " Quelques considérations sur les gisements de pétrole du Sud de la France ", he outlined the history of the search for oil in southern France, and briefly described the structure and stratigraphical history of the Aquitaine basin, the Petites-Pyrénées, and the Languedoc basin. In recent years the search has resulted in the discovery of substantial gas production and a small output of oil, in addition to revealing some shows of oil. Possible source rocks range in age from basal Oligocene to Lower Permian, the Middle and Upper Cretaceous and the Lower Permian being the most likely sources. Geophysical and geological work and drilling have thrown new light on the stratigraphy and tectonics of this region. There is evidence of the former existence of an ancient cordillera north of the Pyrenean front.

In August, 1947, a well near the axis of the Anadarko basin in Oklahoma was abandoned at a depth of 17,823 feet. In speaking on the " Significance of the world's deepest well bore ", R. R. Wheeler (U.S.A.) remarked that there were some evidences of oil at 8,200 feet, but a drillstem test was inconclusive. 3,500 feet of Deese beds were found resting unconformably on Atoka limestones and sandstones, affording confirmatory evidence that the Arbuckle-Wichita orogenic movements were initiated in early Pennsylvanian times and culminated in post-Atoka pre-Des Moines time, i.e. at a later date than has long been assumed by Mid-Continent geologists. A lateral shift of the structural axis at depth was indicated, a phenomenon which was considered in general terms in the following paper by H. R. Tainsh (Burma) on " An aid to the forecasting of underground structures ". Tainsh made a plea for the formation of a collection of geological cross-sections carefully compiled from surface and subsurface data on structures showing strong dips, because these would probably be of value in guiding deep exploration on previously unexplored structures, and would provide material for the detailed analysis of folding, especially in incompetent beds.

W. B. Wilson (U.S.A.), who gave a paper on " Some aspects of petroleum migration ", contended that a flattening of the dip of the formations was in itself not sufficient to give a commercial oil accumulation. He believed that oil migrated at an early date. At times this migration may have been before structural traps had been formed, although stratigraphic traps might be available.

The second meeting consisted of a series of papers on the Middle East and near-by areas. G. M. Lees outlined the principal features of the main area in a paper on " Some structural and stratigraphic aspects of the oilfields of the Middle East ". Sediments from Cambrian to the Tertiary showing no marked discordance are present in this region. From the Permian onwards sedimentation was fairly continuous and dominantly calcareous. In detail the rocks change towards the Arabian foreland, the chief difference between this and the Iranian area being the absence of a great thickness of Tertiary in the former. Strong structures occur in the Iran and Iraq oilfield areas, and to the north-east, but towards the Arabian shield dips are generally less than 3°–4°.

In Iran and Iraq the first big barrier to upward migration of oil is the Lower Fars series, and oil production has been obtained from the immediately underlying Asmari and Main Limestone series, respectively, in these two countries. Many possibilities exist with regard to source rocks—Asmari, Eocene, Upper, Middle, and Lower Cretaceous, Jurassic, Triassic, and even Cambrian rocks—and there are vertical fissure connections with the reservoir rocks. Live oil noted in some Cretaceous cores may be in process of upward migration.

Towards the Arabian foreland there are considerable developments of anhydrites which can act as cap-rocks. The source of the oil is not settled, but there is oil in the Jurassic and Cretaceous.

In the Iran oilfield area are anticlines as much as 200–250 miles long. The incompetence of the Fars series has given rise to extreme disharmony between the surface and deeper structures. Surface synclines have been found over subsurface anticlines.

The salt dome structures of Iran are subsidiary to the main folds amongst which they are found. There are dead salt plugs which have apparently exhausted the parent salt bed, and active plugs which seem to be in a kind of hydrostatic equilibrium with the enclosing sediments.

In a paper on " The Asmari Limestone of south-west Iran ", A. N. Thomas (Iran) discussed lateral variation and correlation in the Asmari. He concluded that in the wide sense the term Asmari Limestone formation should include the underlying Brissopsis Beds, the Kalhur Limestone of the Khanaquin district, and probably also the Khamir Limestone. Some parts of the Asmari were deposited under conditions believed to be favourable for oil formation, and it was considered that the Asmari oil might therefore be indigenous.

The following paper, by F. R. S. Henson, was on " The stratigraphy of the Main Producing Limestone of the Kirkuk oilfield ". A description of the general pattern of typical Middle East reef complexes was given, and the petrological and physical characteristics of the main parts, together with the environment of formation, were described. A stratigraphic break immediately above the reservoir over much of the Kirkuk structure was considered to afford evidence on the time of oil accumulation and on the age of the oil source rock.

The structural complexities of the Iranian oilfield belt were the subject of a paper by C. A. E. O'Brien on " Tectonic problems of the oilfield belt of south-west Iran ". O'Brien considers that the salt-laden Lower Fars Series constitutes a mobile group between competent pre-Fars beds and incompetent Fars-Bakhtiari deposits, and is largely responsible for the extraordinary structural differences between the Asmari limestone and the surface beds. Orogenic movements are believed to have formed great anticlinal structures in competent pre-Fars beds, and the overlying plastic series is thought to have reacted in close conformity with the laws of hydrostatics, leading to the flow of salt from high pressure areas over rising anticlines into adjacent synclinal areas.

E. R. Gee's paper on " Petroleum geology in Pakistan ", presented by H. Crookshank, dealt chiefly with Western Pakistan, and summarized the geological history and stratigraphy. A brief account of the oil exploration and exploitation was included.

In a paper on " The stratigraphy of the Alexandretta Gulf Basin ",

C. E. Tasman (Turkey) noted that in the basin and adjacent uplands were some 30,000 feet of sediments, ranging in age from Silurian to Quaternary. Quartzites and dolomites topped by Carboniferous shales represented the Palaeozoic, whilst the Mesozoic was marked principally by limestones. The Tertiary, which accounted for two-thirds of the total sequence, and was mostly Miocene, contained shales, sandstones, and conglomerates of neritic and continental origin.

The foregoing group of papers provoked considerable discussion, in the course of which J. L. Rich (U.S.A.) expressed doubt about the feasibility of the mechanism involved in the tectogene concept. L. G. Weeks (U.S.A.) contended that there were many prolific oil-bearing basins in which bituminous oil-smelling strata were absent or of minor importance, while other basins had large amounts of highly bituminous strata with no oil. He believed that source and reservoir rocks could be contemporaneous, and that the presence of a stratigraphic break immediately above the reservoir rock was not always conclusive evidence against such a possibility. W. L. F. Nuttall drew attention to a break and reef conditions in the " Golden Lane " of Mexico comparable with those of Kirkuk.

The last meeting began with a paper on " The oilfield of Ganso Azul, Peruvian Amazonas region ", by A. Heim (Switzerland), and was followed by one on " Some outlines on the tectonics of the Upper Amazon embayment ", by W. Rüegg (Peru) and D. Fyfe, read by J. V. Harrison. Ganzo Azul obtains light oil from the Cretaceous at depths of about 1,000 feet. Permian beds occur below the Cretaceous. Rüegg and Fyfe also noted the large stratigraphic gap underneath the Lower Cretaceous, and pointed out that both conformable and angular contacts were known. Differences in age, mobility, and position of the individual structural blocks of this region were postulated to explain this feature.

In their paper on " The Atlantic Coastal Plain ", read by R. R. Wheeler (U.S.A.), H. W. Straley (U.S.A.) and H. G. Richards (U.S.A.) reviewed the stratigraphy of the coastal plain between New Jersey and Florida. Numerous deep water- and oil-wells have provided new information on this area. The authors concluded that the oil possibilities of the coastal plain cannot yet be said to have been adequately tested, and they suggested that the Berlin–Salisbury embayment in Maryland, the Pamlico Sound basin in North Carolina, the Beaufort basin in South Carolina, and the Okefeeoke basin in south-eastern Georgia and north-eastern Florida merit further testing. In discussing Straley and Richard's paper, R. B. Campbell (U.S.A.) remarked that the Cape Hatteras well (North Carolina) had revealed a marine section regarded as favourable for oil occurrence. Palaeozoic formations, predominantly black shales, had been discovered beneath

the Mesozoic and Tertiary in the Florida–Georgia region, thus revealing the south-eastern margin of the ancient land mass of " Appalachia ", which hitherto had been regarded by many as lying far out in the Atlantic.

The concluding paper was by T. D. Weatherhead, on " Air survey and geology ". After enumerating the types of information and the advantages which can be obtained by the use of aerial photography, Weatherhead described the types of aircraft employed, the equipment used in the photographic flights, and the apparatus and techniques used in map production. Stereoscopy, the obtaining of geological information from the photographs and the most suitable photographic scales were briefly discussed.

Section F. Geology, Paragenesis, and Reserves of the Ores of Lead and Zinc

By K. C. DUNHAM

Introducing the work of the section, Professor W. R. Jones remarked that the eight years which had passed since the decision to include a symposium on lead and zinc ores in the programme of the Eighteenth International Geological Congress was taken had witnessed great changes in the industrial position of these minerals ; they were now among those most seriously in short supply. At present 70 per cent of world output came from only five countries, and half of this originated in the U.S.A. Moreover, during the present century as much lead and zinc had been mined as in the whole of previous history.

Members of the session had before them a specially prepared symposium containing twenty-three papers covering the principal genetic types of lead and zinc deposits, contributed by experts from all parts of the world, and edited by K. C. Dunham. In summary form the geological features of the 114 principal lead-zinc districts of the world were correlated with data on reserves and production. The data suggested a life of nineteen years for lead and twenty-six years for zinc at the current rate of production.

The increasing importance of the high-temperature deposits of Northern Sweden was evident from descriptions by Erland Grip (Sweden) and Nils H. Magnusson (Sweden). Another potentially important new source, discovered in 1936 at Mpanda, Tanganyika, but only now being brought into production, was the subject of a paper by the discoverer, J. de la Vallée Poussin, presented by R. B. McConnell (Tanganyika). In discussion of this paper, and of another by R. A. Mackay describing deposits in Nigeria, the important fact emerged

that in the tropics very few lead-zinc deposits have been found. Speakers, including W. D. Johnston, jun. (U.S.A.), drew attention to the possibility that this was because weathering was very deep and complete ; beneath the surface layer important deposits may remain undiscovered. At Mpanda there is still evidence of oxidation at a depth of 2,300 feet, but Poussin suggested that much of the weathering here was probably accomplished in Pre-Cambrian times. Further investigation of the effects of tropical weathering upon lead-zinc deposits is evidently desirable ; Mackay maintained, for example, that under certain conditions in the tropics, galena might be precipitated near the water-table, an effect unknown in temperate climates.

Second only to the United States among world producers of lead and zinc ores, Mexico contains many important mines, though as yet the geology of few of them has been recorded in the literature. J. Gonzalez Reyna (Mexico) presented a valuable review of the situation, and concluded that the northern part of the Republic, along the western Sierra Madre, offers most promise for new discoveries.

Emphasis was moved from new discovery to adequate development and equipment in existing fields by C. B. Forgan in describing the Stantrg Mine in Yugoslavia, developed by British interests before the war. Forgan considered that what is required in the immediate future is the creation of economic conditions capable of providing stimulus and long-term confidence in investigation and equipment of known potentialities.

Further important contributions to the geology of lead and zinc fields in the Mediterranean region were made by S. Vardabasso and P. Zuffardi (Sardinia), by J. Agard, J. Bouladon, F. Permingeat, and G. Jouravsky (Morocco), by P. Sainfeld (Tunisia) and G. Marinos (Greece). Published estimates of reserves for this region appear from this survey to be decidedly too low, a reassuring fact for the future of European non-ferrous metals industries.

Describing the widespread dissemination of small amounts of galena and blende in deposits of Permian age in Poland, Germany, and the north of England, T. Deans maintained that these represented the best examples of syngenetic deposits. The new data showed that more lead and zinc than copper is present in the Kupferschiefer, when this formation is viewed as a whole.

Epigenetic deposits in limestone, of moderate—to low—temperature type were described from Millclose, Derbyshire, by J. Shirley ; and by D. di Colbertaldo (Italy), from Raibl, Cave del Predil.

The whole discussion gave promise of activity in many parts of the world by geologists in an effort to contribute both to the immediate problem of ensuring adequate supplies of the metals and to the fundamental problems of the origin and emplacement of lead-zinc deposits.

Section G. The Geology of Sea and Ocean Floors

By W. B. HARLAND

The papers read to this section did not result in any general conclusions, but rather demonstrated a great development in the organization and technique of survey. In this respect the increasing co-operation of Navies with University departments is shown to result in a new order of available data. In addition, however, there is a considerable increase in the number and variety of purely academic attempts at ocean exploration.

At the first meeting, with Professor O. T. Jones, and subsequently Professor J. S. Lee (China), in the Chair, the following presented papers: J. Bourcart (France), R. D. Russell (U.S.A.), R. A. Sonder (Switzerland), A. C. Tester (U.S.A.), J. H. F. Umbgrove (Netherlands), and J. W. Wells (U.S.A.); and at the second meeting, with Professor J. H. F. Umbgrove (Netherlands) and Dr. R. M. Field (U.S.A.) in the Chair, E. M. Gallitelli (Italy), R. M. Field, J. S. Lee, Z. Sujkowski (Poland), and P. H. Kuenen (Netherlands) read papers, and the last showed a film.

The data presented indicated but briefly what was in many cases already published or to be published elsewhere. Developments in exploration technique include improved echo sounding which has been extensively used in detailed surveys of many continental shelves and pacific islands. Submarine photography is a new and promising contribution to geology. New designs for submarine exploratory vessels are expected. Seismic and gravity surveys are also being extended increasingly to the seas and oceans. An ambitious programme of surface drilling in Bikini was described. Sampling by submarine coring devices is being rapidly developed and, in addition to increased knowledge of contemporary marine deposits, there is the prospect in the next few years that ocean stratigraphy may challenge many current ideas on the later history of the earth.

All these methods have been known and used before. The present stage marks an intensification of effort when the isolated data so far described may be found to be more or less typical of widespread conditions. The results of different techniques are being co-ordinated as never before as, for instance, in the U.S. Navy exploration of Bikini Atoll.

Certain generalizations were attempted and the pattern of ocean geology in the next decade may be discerned. The nature of sedimentation at great depths as reflecting differing conditions remains an important field of research. For instance, the chemical changes involved in the formation of manganese nodules was discussed. It seems that submarine canyons are characteristic of continental shelves

rather than an interesting exception, and their formation remains a mystery though it is probable that high density turbidity currents as well as slumping operate in them. It may be possible, especially when the submarine surface has been further explored, to demonstrate certain preferred levels as indicated by submarine features such as continental shelves, island terraces, canyons, and mountains, and so disentangle widespread isostatic from superimposed eustatic changes. Such an attempt was made at this meeting. The Pacific ocean, with its coral islands, is the area where this problem is most actively pursued, and further light on the structure and movements of the floor of the Pacific may be expected. Island arcs, as in S.E. Asia, begin to show a characteristic structural pattern, and speculation on their origin supported by geophysical data may lead to a working hypothesis of orogenesis. The venerable concept of the geosyncline comes again under review and in modern dress seems likely to retain a leading role. The next decade may well define that dress.

Section H. The Pliocene-Pleistocene Boundary

By K. P. OAKLEY

Professor W. B. R. King, who acted as Chairman of this symposium, outlined the various criteria which have been proposed for delimiting the Pleistocene, and stressed the desirability of selecting a type locality where one or more of these theoretical concepts can be tied to actual strata. He favoured Italy as type area, and suggested that the question to decide was whether the lower boundary of the Pleistocene should be drawn at the base of the Calabrian-Villafranchian, or at the top.

H. L. Movius (U.S.A.) reviewed the stratigraphy of the Villafranchian deposits of Italy, East and Central France, and drew the conclusion that they were approximately contemporary with the onset of glaciation in the Alps.

In a joint discussion with Section K (The Correlation of Continental Vertebrate-bearing Rocks) A. T. Hopwood called attention to the practical value of regarding the Villafranchian as basal member of the Pleistocene, since it was distinguished by a widespread mammalian fauna, including *Elephas*, *Equus*, and advanced bovines, which permitted correlation from continent to continent. Mlle. M. Friant (France) spoke of the importance of elephants as guide-fossils in the Pleistocene.

F. E. Zeuner pointed out the difficulties inherent in the use of glaciation or the appearance of certain mammalian genera for delimiting the Pleistocene, since these criteria were inapplicable in non-glaciated or unfossiliferous regions. He favoured physiographic criteria, and

suggested that the drop in sea-level from around the 100-metre mark during the Sicilian stage would afford one possible boundary for the base of the Pleistocene, since it initiated a new erosional cycle widely recognizable on the continents. He was of opinion that the cool elements in the Villafranchian fauna and flora might correspond with the Pre-Günz (Donau) phases of glaciation in the Alps, but further work was needed to prove this correlation. Villafranchian deposits were of great thickness, and if the Pleistocene were extended to include them the Lower Pleistocene would be out of proportion to the Middle and Upper.

P. Woldstedt (Germany) reviewed the evidence of early glaciations in Europe. In periglacial parts of Germany there were six so-called "preglacial" terraces, some of which probably recorded Eberl's Donau (Pre-Günz) phases of glaciation.

The various criteria which have been used in the East Indies for delimiting the Pleistocene were discussed by G. L. S. Sibinga (Netherlands). He found marine regression, based on glacial eustasy, the most convenient. R. J. Russell (U.S.A.) also found physiographic criteria the most practical. He recounted evidence from bores 30 miles from the shore in the Gulf of Mexico, which proved an oxidized zone in sediments below Recent marsh-delta deposits at a depth of 550 feet, clearly marking the late Pleistocene regression of the sea.

E. Feruglio (Argentine) contributed an account of the marine terraces in Patagonia. The molluscan faunas of the higher terraces (170–186 m., 115–140 m.) contained 30–40 per cent extinct species, and he regarded them as Upper Pliocene. The main Pleistocene terraces are at elevations of 45–95 m., 15–30 m., and 8–12 m.

C. I. Migliorini (Italy) reviewed recently obtained data regarding the marine succession in Italy, and claimed that the base of the Pleistocene was best drawn between the Astian and the Calabrian, since faunal change at this horizon is well marked, whereas the Calabrian and Sicilian are scarcely separable palaeontologically. Moreover, there is evidence of pronounced climatic cooling between the Astian and the Calabrian.

R. Selli (Italy) gave an account of his work with G. Ruggieri (Italy) on the Plio-Pleistocene stratigraphy in Emilia (North Italy), and made out a strong case for regarding the Calabrian (*sensu stricto*), which he regarded as equivalent to Pre-Günz and Günz, as the basal stage of the Pleistocene. A new unit, Calabrian II or Emilian, with mild climate fauna, is recognizable between Calabrian (*s.s.*) and Sicilian. The speaker indicated that two sets of deposits had been classed as "Sicilian", the earlier being Sicilian *sensu stricto*, the later equivalent to Milazzian.

In a written communication, J. M. Ribera-Faig (Spain) reported

that continental beds of Astian age in the Catalonian province of Spain, were followed by erosional stages, caliche formation, and river terraces, the higher of which contained Lower Pleistocene fauna.

A. Desio (Italy) outlined present-day knowledge of the Pliocene and Pleistocene geology of Libya. The presence of marine deposits of Pliocene age in Libya is still uncertain. The Mio-Pliocene continental beds with mammalian remains at Sahabi, Sirtica, are most important for correlation with other countries.

C. Arambourg (France), in a written communication, and L. S. B. Leakey (Kenya) discussed the Pleistocene stratigraphy and palaeontology of Africa, especially the application of the terminology advocated at the Pan-African Congress on Prehistory (Nairobi, 1947). Leakey pointed out that in East Africa, deposits of the Kageran stage (whose fauna is equivalent to the Villafranchian) contained pebble-tool industries, representing the earliest known human cultures. It was logical and convenient, he said, to regard this stage as forming the base of the Pleistocene. For faunal and geological reasons it appeared desirable to divide the Kamasian into lower and upper stages. According to Arambourg, the classification of the Pleistocene recommended at Nairobi (*L'Anthropologie*, 51, p. 258) is proving applicable to the North African as well as to the East African faunal succession. He said that the Neanderthaloid jaw, found at Rabat, Morocco, was associated with an Upper Kamasian fauna.

C. C. Young (China) submitted a paper in which he discussed the question as to whether the lower boundary of the Pleistocene in China should be placed at the bottom or at the top of the Nihowan stage. The latter boundary (i.e. approximately base of Choukoutien stage) has been adopted by the Caenozoic Research Laboratory.

According to D. N. Wadia (India) no definite natural break serving to separate Pleistocene from Pliocene can be discerned in the great thickness of deposits preserved in the N.W. Sub-Himalayas.

G. H. R. von Koenigswald (Netherlands) outlined recent discoveries of fossil man in Java. He said that remains of three types of man had been recovered from deposits now classified by most workers as Lower Pleistocene : *Pithecanthropus robustus* Weidenreich (probably synonym of *P. modjokertensis* (v. Koenigswald)) ; *P. dubius* v. Koengiswald, and *Meganthropus palaeojavanicus* v. Koenigswald. The speaker claimed that the Trinil Beds, which yielded the genotype of *Pithecanthropus*, were later, and should be classed as Middle Pleistocene. He equated the Trinil Beds with the Choukoutien stage of China.

H. E. Thalmann (Venezuela), in a paper submitted in writing, discussed the foraminiferal evidence of a Pliocene-Pleistocene boundary. He noted five genera of foraminifera restricted to the Pleistocene : *Bifarinella*, *Geminospira*, *Oolitella*, *Polymorphinoides*, and *Unicosiphonia*.

I. M. van der Vlerk (Netherlands) and A. J. Pannekoek (Netherlands) spoke on behalf of a team of workers now actively engaged on elucidating Plio-Pleistocene stratigraphy and palaeontology in the Netherlands. On the basis mainly of foraminiferal evidence, van der Vlerk claimed that in the East Anglian succession the base of the Butleyan was the natural place to draw the Plio-Pleistocene boundary. A marked recession of the sea occurred during this stage. Moreover, elephants made their first appearance in the equivalent continental beds in the Netherlands (*Archidiskodon planifrons* in the Pretiglian stage). F. Florschütz (Netherlands) and Miss A. M. H. van Someren (Netherlands) submitted a paper on the palaeobotanical boundary Pliocene-Pleistocene, and showed that the Reuverian (Upper Pliocene) and Tiglian (Lower Pleistocene) clays can be separated by pollen-analysis.

While the discussions of Section H were taking place, the Council of the Eighteenth Session appointed a Temporary Commission to advise on the definition of the Pliocene-Pleistocene boundary. The Commission was able to forward a unanimous opinion in the following terms :—

(1) The Commission considers that it is necessary to select a type-area where the Pliocene-Pleistocene (Tertiary-Quaternary) boundary can be drawn in accordance with stratigraphical principles.

(2) The Commission considers that the Pliocene-Pleistocene boundary should be based on changes in marine faunas, since this is the classic method of grouping fossiliferous strata. The classic area of marine sedimentation in Italy is regarded as the area where this principle can be implemented best. It is here too that terrestrial [continental] equivalents of the marine faunas under consideration can be determined.

(3) The Commission recommends that, in order to eliminate existing ambiguities, the Lower Pleistocene should include as its basal member in the type-area the Calabrian formation (marine) together with its terrestrial [continental] equivalent the Villafranchian.

(4) The Commission notes that according to evidence given this usage would place the boundary at the horizon of the first indication of climatic deterioration in the Italian Neogene succession.

The Commission's recommendations were unanimously accepted by the Council at its meeting on 1st September, 1948. Some of the implications of the definition recommended are discussed in *Nature*, 163, p. 186.

Section J. Faunal and Floral Facies and Zonal Correlation

By H. Dighton Thomas

Dr. A. E. Trueman, followed by Professor B. Sahni (India), in the First Session ; Professor R. Kozlowski (Poland) and Professor G. G. Delépine (France) in the Second Session ; and Professor C. Poulsen (Denmark) and Dr. A. E. Trueman in the Third Session, acted as successive Chairmen.

A. Renier (Belgium) clearly posed the problem of faunas and floras in making correlations and their importance to stratigraphy, palaeogeography, and palaeoclimatology, and argued that age and facies should be considered together. Local correlations are not capable of unlimited extension, and palaeontological knowledge should be applied with intelligence. L. R. Wilson (U.S.A.) showed how fossil spores and pollen from some early Tertiary coals and shales of Montana and Wyoming not only give information on the correlation of the rocks, but also throw light on the palaeoecology and palaeoclimatology of those areas at that time. S. J. Dijkstra (Netherlands) demonstrated the value of megaspores in the correlation of Turkish coal deposits. From an analysis of the flora of the Lower Brown Limestone of North Wales, W. S. Lacey suggested that that limestone should be correlated with the lowest part of the Scottish Oil Shales and the equivalent beds in Northern England, and claimed that there is faunal support for this. T. N. George pointed out the dangers of this correlation made by jumping from the Avon Gorge to North Wales and thence to Scotland, since big facies changes are involved. He elaborated this theme in the Second Session in a paper on Tournaisian facies in Britain, in which he pointed out that the restricted Tournaisian fauna in northern Britain makes correlation very difficult, and suggested that some rocks of Old Red Sandstone facies may be of Carboniferous age in the Midland Valley of Scotland. T. S. Westoll emphasized the importance of the *Bothriolepis–Holoptychius–Phyllolepis* fauna in discussions on the boundary between the Upper Old Red Sandstone and the Lower Carboniferous.

Y. C. Sun (China) discussed the Palaeozoic faunas of Asia and Europe, and concluded that the Pacific was a main centre of dispersal of early Palaeozoic life. He claimed that the completeness of the Yunnan succession made it the best standard in classifying the world's Palaeozoic, and he showed there was a close connection between the Mediterranean Sea and the Cathaysian Province. His ideas were welcomed by G. G. Delépine (France), who quoted Devonian and Carboniferous goniatites, as well as fusulinids, in support. A. Lamont analysed the Silurian fauna of the Pentlands, particularly the Gala-Tarannon, and claimed a new division, the Pentlandian, of the Silurian

system. In the discussion on a paper by E. B. Branson (U.S.A.) and M. G. Mehl (U.S.A.), who showed how conodonts have been used in correlating stages, B. F. Howell (U.S.A.) drew attention to two impressions of what appear to have been fish plates in the Middle Cambrian of Vermont. L. S. Librovich (U.S.S.R.) discussed the faunistic subdivision and correlation of the Lower Carboniferous of the U.S.S.R., and emphasized that on faunal grounds the Namurian in Russia is better classified with the Lower Carboniferous than with the Middle Carboniferous, though, as Trueman later pointed out, the greater part of the Namurian in Britain and Western Europe forms a natural part of the Upper (or Middle) Carboniferous. J. J. Gorsky (U.S.S.R.), discussing the coral zones of the Upper Palaeozoic of the Urals, showed that the coral fauna of Pz3 is a local one, which has developed from an Upper Viséan fauna, and that it is of restricted value in correlation : he emphasized the importance of narrowly defining species.

In the closing Session T. M. Harris showed that in the flora of the Yorkshire Estuarine Series many plant species are frequent in the first and last of its four stages, but absent from its two middle ones, while others characterize the two middle ones alone. He objected to the term " Estuarine " and preferred " Deltaic " as more appropriate, but P. C. Sylvester-Bradley favoured the former on the grounds of priority. There were two papers on fresh-water mollusca of the Mesozoic by T. C. Yen (U.S.A.), who claimed that parallel development took place in them contemporaneously in separated basins, and that the stages reached in the evolution of shell characters could be used for correlation. On this basis he inferred that the Morrison formation of North America is probably older than the greater part of the Purbeckian of N.W. Europe, and that it possibly represents a freshwater facies of the Portlandian. Two papers by K. F. G. Mullerried (Mexico) dealt with the marine and continental facies of the Mesozoic of Mexico and Central America, particularly the Cretaceous. A final paper, by A. N. Thomas (Iran), demonstrated variation in the foraminiferal biofacies of the Asmari Limestone of Iran.

In a valuable summing-up of the discussions of the Section Trueman pointed out how various are the organisms now used for correlation by palaeontologists ; even some of the most unpromising are important locally. Some local correlations have proved applicable over unexpectedly wide areas, but others naturally broke down when similarly extended, especially if they were dependent on facies. Both faunal and floral evidence are valuable and, if proper regard be had for facies variations, must lead to the same conclusion. But where the evidence is incomplete correlations must be recognized as only tentative. Trueman emphasized the difficulties in erecting a satisfactory and

universally acceptable stratigraphical classification, and mentioned the placing of the Namurian as a good example. The narrower stratigraphical divisions can generally be identified only over lesser horizontal distances ; world-wide correlations must be based on broad divisions whose boundaries become increasingly vague with distance.

Section K. The Correlation of Continental Vertebrate-bearing Rocks

By W. E. Swinton

Professor D. M. S. Watson acted as Chairman throughout and introduced the subject matter of each session. At the first session T. S. Westoll dealt with the vertebrate-bearing strata of Scotland in the light of his own researches. His conclusions are that the so-called Downtonian fish bed of Lesmahagow and the Pentlands is earlier than Downtonian but later than Llandovery-Valentian. The Cowie Harbour fish bed is Downtonian and Upper Downtonian faunas are not known. The main fossiliferous horizons of the " Lower Old Red " are Dittonian. He regards the Old Red Carboniferous boundary as arbitrary and thinks the Lower Calciferous Series may be the equivalent of the *Remigolepis*-zone and higher beds of Greenland. E. Stensiö (Sweden) objected to this last assumption on the ground that the vertebrate faunas were not directly comparable.

T. S. Westoll believes that the Lepospondyli, the oldest vertebrates in Scotland, are of Middle and late Viséan age, and that the vertebrate faunas of the Productive Coal Measures are Westphalian A-B.

E. J. White discussed the palaeontological zoning of the Downtonian and Dittonian strata of the Welsh borders, and gave the division between the two as the base of the zone of *Pteraspis leathensis*. He believes that the natural palaeontological break in this region between the Silurian and the Old Red Sandstone is at the base of the Ludlow Bone Bed, and he therefore concludes that the Downtonian strata should be included in the Devonian as part of the Old Red Sandstone.

The second session of Section K was a joint one with Section H and is already summarized under the proceedings of that Section. The proceedings were remarkable for the unanimity of the specialists in accepting the inclusion of the Villafranchian in the Lower Pleistocene.

The final meeting covered a wide stratigraphical range, from the Lower Trias to the Miocene. Mlle. M. Richard (Algeria) stressed the stratigraphical importance of the mammalian faunas of the Eocene, Oligocene, and Miocene, illustrating her remarks by reference to the French succession. D. M. S. Watson stressed the importance of this succession and said it was time that a serious attempt was made to

correlate it with the American sequence. T. M. Stout (U.S.A.) said that the work done on the Great Plains mammal succession, from the base of the Oligocene to the Pleistocene, made such a correlation much less difficult.

S. P. Welles (U.S.A.) gave an account of the very comprehensive collection of Amphibia he had made in the Trias (Moenkopi) beds of Northern Arizona, where in one locality he found numerous examples of forms, like *Aphaneramma*, *Capitosaurus*, and *Cyclotosaurus*, otherwise represented by unique, or very few, specimens from Spitsbergen, Germany, and South Africa.

E. H. Colbert (U.S.A.) described a remarkable find of dinosaur remains in the Upper Triassic (Chinle) beds of New Mexico. The principal discovery was a series of skeletons of *Coelophysis*, a small Theropod known as far only from fragments. The new material will not only give full details of the skeleton, but should provide evidence as to age, and perhaps sexual, differences in these interesting reptiles.

Section L. Earth Movement and Organic Evolution

By H. L. Hawkins

In his introductory remarks the Chairman, Professor H. L. Hawkins, stressed the importance of the topic with which this section was concerned. The problems of the relation between environmental changes and the evolution of organisms are fundamental to both geology and biology, for faunal and floral facies and migrations may seriously affect the correlation of disconnected strata, while the adaptation of organisms to their surroundings is a major aspect of the study of evolution.

The six papers presented to the section covered a variety of topics, some local, others regional, and others world-wide. They are here taken in an order consistent with that grouping, and not in the order of their reading.

L. V. Cepek (Czechoslovakia), in his paper entitled " Palaeozoic earth-movements and organic evolution ", gave a detailed account of the stratigraphy of the Coal Measures in some Czechoslovakian coal-basins, and showed the relation between contemporary rift-faulting and the quality and quantity of coal developed in different parts of the basins ; the thickness and rank of the coals reflecting the varying circumstances of their accumulation.

D. Andrusov (Czechoslovakia), speaking on " Mouvements orogéniques, sédimentation et évolution de la vie dans les Carpathes occidentales ", gave a summary of the stratigraphical and tectonic history of the district, and discussed the influence of these phenomena

on the faunal successions. He laid special stress on the connection between bathymetric conditions and the nature of the fauna, and on the influence on migration of the opening and closing of routes of communication by tectonic movement.

A. Chavan (France) read a paper "Sur les causes de certaines migrations de faunes avant et pendant l'Eocène", in which he covered a wider geographical field but a more restricted stratigraphical range. After describing the occurrence of many genera of tropical Mollusca in the Lower Cainozoic systems of north-west Europe, he suggested that it might be explained as the result of migration made possible by great geographical changes, including the development of the Atlantic Ocean.

A paper by V. A. Obruchev (U.S.S.R.) on "The fundamental features of the Kinetics and plastics of neotectonics" was, in the absence of the author, read in title only. In it the influence of orogenic and climatic changes on organic evolution was carried up into the Pleistocene.

K. Zapletal (Czechoslovakia), in his paper on "Geochemie, Rhythmus der Sedimentation und organische Entwicklung im Lichte der Tektogenesis", ranged over still wider territory, correlating orogenies and sedimentary cycles the world over, and throughout geological time, with magmatic modification and the succession of organic life. He indicated the close relation between times and places of vigorous tectonic activity and centres of important organic evolution and dispersal.

Lastly, R. C. Moore (U.S.A.) discussed the matter from a biological rather than a tectonic angle, demonstrating in the group of the Crinoidea the coincidence between the inception and extinction of the several divisions of the group and the main orogenic paroxysms of geological history. His detailed analysis of the distribution in time and space of the various orders of Crinoidea gives valuable evidence of palaeogeographical changes, and of the faunal response to them as shown by migration, extinction, and evolution.

Section M. Other Subjects

By R. M. SHACKLETON

The Other Subjects Section (M) of the Congress, under the Chairmanship of Sir Edward Bailey, with Professor Leon Collet (Switzerland) as alternative Chairman, held six sessions, at which twenty-seven papers were presented.

The majority of the papers dealt with tectonic problems—with earth movements and structural geology; it was therefore fitting that

L. Collet (Switzerland) should begin by presenting to the Congress the first four of eight geological sheets which will cover the whole of Switzerland, where better than anywhere else in the world, the amazing results of the movements of crustal strata are laid bare to the geologist. The maps co-ordinate an immense body of work and will be of value to tectonicians the world over.

Relative Movements of the Land and Ocean Surfaces

Several papers were concerned with this subject. An unusually fine series of stranded Pleistocene sea-beaches in South Australia was described by R. C. Sprigg (Australia). Climatic conditions favoured rapid surface calcification of the dunes, which were thus preserved intact. Some seventeen sea-level maxima, superimposed on a generally falling sea level, suggested at least a numerical similarity with the number of maxima predicted in the Pleistocene period by the theories of Milankovitch and Zeuner. In discussion, F. E. Zeuner, impressed but cautious, summed up his remarks by saying " we have in our curve a possible seventeen maxima. R. C. Sprigg has about the same number. Let us take note of this agreement."

A fundamental paper by L. von Post (Sweden), presented by N. G. Hörner (Sweden) showed, by analysis of the wealth of data from Sweden, that various factors governing the late Quaternary displacement of the sea shore could be separated and evaluated. Besides eustatic changes of sea level and isostatic rise of the land after the removal of the load of ice, it was also necessary to postulate pulsatory movements of subcrustal material. A. J. Bull discussed the correlation of river terraces and sea levels in southern England through the Pleistocene period.

Earthquakes and Tectonics of Turkey

The relation between earthquakes and major tectonic features of Turkey was the subject of a paper by H. N. Pamir (Turkey). M. M. Blumenthal (Turkey) discussed the tectonics of Turkey, referring especially to the variable direction of crustal movement in different parts of the region during the Alpine orogeny.

Gravitional Sliding in Orogeny

The part played by sliding under the influence of gravity was the subject of a series of papers. L. Collet (Switzerland) discussed the various possible interpretations which might be applied to explain masses of granitic or other crystalline rocks embedded in a sedimentary series. Describing the evidence in certain particular cases in the High Calcareous Alps, he inferred that these were probably best interpreted as submarine landslip masses, which slid into the Jurassic sea. This

would imply a mountainous Jurassic topography. It is now known, said L. Collet, that such a Jurassic landscape did exist there.

W. J. McCallien (Turkey) and M. Tokay (Turkey) produced striking evidence for a slumped or landslide origin of great masses of Carboniferous rocks (one so large that coal is mined in it) which are embedded in the Cretaceous rocks of the Black Sea region between Zonguldak and Eregli.

A more revolutionary conception of the part played by sliding in orogeny was advanced by C. I. Migliorini (Italy) and supported by G. Merla (Italy) to explain the nature and relationships of the *Argille scagliose*, which forms the so-called Ligurid nappe of the Apennines. According to Migliorini, this nappe, which in places rests on formations as young as Pliocene, is supposed to have advanced some 200 km., yet it is nowhere more than a few hundred metres thick and it was never over-ridden. It could not have been pushed from behind. The evidence indicates movement under gravity. The mechanism suggested is the upthrust of a series of crustal wedges, bounded by downwardly convergent normal and reversed faults; orogenic landslips developed from each successively uplifted wedge, leaving behind tectonic wrecks scarred by tectonic erosion.

In the discussion, G. M. Lees objected to the use made of the conception of isostasy to explain the recurrent uplift of the wedges after their tectonic denudation. The Alpine geologists were not drawn into the discussion, of which more will no doubt be heard.

Carrying the idea of sliding further into the depths of the crust, J. L. Rich (U.S.A.) outlined a theory of orogenesis based on the idea that the crust slides off the edge of sheets of magma which develop owing to radioactive heating. R. M. Shackleton thought that on this theory one would expect orogenic girdles marking the limits of the magma sheets, whereas the dominant orogenic pattern seemed to be linear; Rich pointed to the West Indian loop and other such patterns as favouring his idea. J. P. Marble (U.S.A.) mentioned recent Swedish work which shows that the radioactive isotope of potassium (K 40) has a greater radioactivity than was formerly thought and probably contributes more heat to the earth's crust than Uranium and Thorium together. Therefore the depth at which radioactive melting would happen would be less than was thought. This agrees with Rich's interpretation.

Tectonics of the Older Mountain Systems of Northern Europe, Greenland, and North America

Great advances have been made in the knowledge of the old mountain systems of the northern regions. In Greenland the young Geological Survey has established the existence of a previously unknown

ancient orogeny. The evidence was described by A. Noe-Nygaard (Denmark). O. Holtedahl (Norway) discussed the relation between the Norwegian Caledonides and the Alps in the light of new work. He showed how much tha had at one time been referred to the pre-Caledonian basement was in fact reconstituted during the Caledonian orogeny.

In the Scottish Highlands, papers by E. B. Bailey and W. Q. Kennedy and E. B. Bailey and C. E. Tilley provided a wealth of evidence—stratigraphical, petrological, and structural—to show that the Torridonian, with its basal conglomerate resting on Lewisian gneiss, can be traced from the foreland, through successive nappes in which the metamorphism increases gradually, into the Moine nappe above the Moine thrust. The Moine schists are thus demonstrated to be the metamorphic equivalents of the Torridonian Sandstones. Their tectonics and metamorphism are Caledonian. This great step forward in Highland geology met little critical opposition, though A. G. MacGregor found that the petrological criteria upon which Kennedy's distinction of Moines from sub-Moines was partly founded were not valid. Kennedy recapitulated the field evidence that the sub-Moines are a tectonic unit distinct from and below the Moines, but admitted the possibility of tectonic intercalations of Moines within the lower tectonic unit.

Still further south, in France, A. Demay (France) showed how it had been possible to trace a detailed tectonic, stratigraphic, and magmatic continuity from southern Armorica into the French Central Massif.

Across the Atlantic the evolution of the mountain systems bordering North America was described by Marshall Kay (U.S.A.). He showed that the conception of vanished borderlands from which the geosynclines were fed with sediment cannot be sustained. Instead, there is evidence of island arcs, largely volcanic, comparable to the east Asian arcs of the present day.

The Andes

An account so brilliantly delivered by E. Feruglio (Argentine) that even those little familiar with his language could follow it, showed how great has been the progress in the mapping and exploration of that region. A. Heim (Switzerland), introduced by E. B. Bailey as the " young Heim ; young, that is, to those who are older ", described the results of his explorations in the central and northern Andes, demonstrating the folds and unconformities in aerial photographs. Alpine style tectonics, however, he found nowhere in evidence.

Magma and Earth Movements

M. Vuagnat (Switzerland) gave the results of a comparative petrological study of the pillow-lavas of the Pre-Alps and those of Britain.

He concluded that the only British pillow-lavas strictly comparable to those of the Alps are those in the Mona Complex of Anglesey. In the discussion A. K. Wells emphasized again the independence of the terms pillow-lava and spilite. O. T. Jones described evidence which shows that certain pillow-lavas were intrusive, presumably into soft muds.

Beautiful examples of cauldron subsidences were mapped many years ago by Brögger in the Oslo region of Norway, but never described. The description now given by C. Oftedahl (Norway) exposed many features of interest.

Earth Movements and Mineralization

Two papers dealt with this theme. Both showed how closely provinces of mineralization correspond with the major tectonic divisions. J. Westerveld (Netherlands) dealt with the East Indies, outlining the geological and metallogenetic history of the region with the aid of a very fine map. A. W. Jolliffe (Canada), describing the results of co-ordinated geological and prospecting work from the air and on the ground, showed that in the north-western part of the Canadian Shield four tectonically distinct zones were each characterized by a distinct mineralization ; some spectacular aerial photographs were shown of straight transcurrent faults, some of which are traceable for several hundred miles across the Shield.

Other Topics : Semi-Permeable Barriers in Mineralization ; Splits and Washouts in Coal Seams ; Frozen Soil Phenomena

R. A. Mackay provoked a lively and mainly favourable discussion in outlining his theory of semi-permeable barriers as a major factor controlling ore deposition. A. A. Thiadens (Netherlands) and J. I. S. Zonneveld (Netherlands) described the relationships seen in washouts in peat deposits and discussed criteria by which the economically important distinction could be made between splits and washouts in coal seams. Q. Zaruba (Czechoslovakia) described frozen-ground structures of Pleistocene age in Czechoslovakia, which were found to be important in engineering problems. The ensuing discussion showed that comparable structures are widespread in northern Europe.

Association of African Geological Surveys

By F. Blondel

The Association of African Geological Surveys, a Sub-Commission of the International Geological Congress, held a series of open meetings

in London during the Congress. The Bureau of the Association, elected during the session, consists of Sir Edward Bailey, Honorary President, Dr. F. Dixey, President, and Mr. F. Blondel, Secretary.

At the first meeting of the Association the Secretary reported on the progress of the preparation of the 1 : 5,000,000 International Geological Map of Africa. This map, which is being produced by the close co-operation of all the African geological surveys, will consist of nine sheets. The first sheet was published in 1936 ; and in spite of delays caused by the war the work is nevertheless making good progress. Four completed sheets were presented to the Congress, and two others are ready for printing. There was every hope that the map will be complete before the next session of the Congress. It will be of very great value in the study of all African geological problems.

In view of the success of this enterprise, the Association requested the Secretary to prepare a general tectonic map of Africa and a general map of the mineral occurrences of the continent. Such maps will also be of great value, both to geologists and mining engineers.

The Association had asked its constituent Surveys to prepare in advance of the Congress brief regional accounts of recent developments in African geology. Fourteen reports were presented, covering almost the whole of the continent of Africa, and will be published in the Report of the Congress. They will form an excellent review of recent geological work in Africa.

The preparation of the map had indicated the need for discussion of certain general problems of African geology, and this was arranged during the meetings of the Association. Among these was correlation in the Precambrian rocks in which metamorphism and the absence of fossils make the application of ordinary geological methods very difficult. A brilliant exposition by A. Holmes of the utility of radioactive methods in the determination of the age of granites enlarged the scope of the discussion and opened up vistas of remarkable discoveries in the future. The study of certain debatable structures known as stromatolites was also a subject of discussion, and the assistance of palaeontological specialists was called in. Finally, still in connection with these ancient series, the evidence of glaciation afforded by their tillites was considered.

At the other end of the time scale the Association studied certain recent formations whose correlation has still to be determined ; attention was given to the division of the Pleistocene as a whole, as set out by the first Pan-African Congress of Prehistory, which was held at Nairobi in 1947 ; and especially to the group of the Kalahari Sands.

Another very attractive topic, the formation and structure of the great Rift Valleys which cut East Africa for thousands of miles, and

which recur in the Jordan Valley, Palestine, was also the subject of many interesting papers.

In addition to these major topics, certain specialized problems were on the agenda, but lack of time permitted discussion of only one of these, the formation of carbonatites.

About thirty detailed papers describing the local geology of various districts scattered throughout the Continent were the final item in this review of the recent work in Africa.

This session of the Association was particularly active and successful. More than fifty geologists contributed to the discussions, and the close personal contacts created or renewed will greatly aid future research on the geology of the African continent.

The International Paleontological Union

By C. J. STUBBLEFIELD

The International Paleontological Union held three open meetings during the Eighteenth International Geological Congress in London in August and the subjects discussed at two of these were designed to have general appeal to palaeontologists. The first meeting took place with the President, Professor P. E. Pruvost (France), in the Chair. The papers communicated related to special aspects of palaeontological publication and bibliography and the first by H. L. Hawkins was a statement of the position in Britain. Reference was made not only to stratigraphical, morphological, and philosophical palaeontological writings but also to the Zoological Record and to S. A. Neave's *Nomenclator Zoologicus*, which indexed all generic names in Zoology and Palaeozoology introduced between 1758 and the end of 1935. Two further papers dealt with special publications appearing in the U.S.A.; the first, by A. S. Warthin, jun. (U.S.A.), communicated by the Secretary, B. F. Howell (U.S.A.), announced progress of the Catalogue of North American Devonian Fossils; and the other by Brooks F. Ellis (U.S.A.) described the history and continuation work of his and Miss A. Messina's Catalogue of Foraminifera. This was published in 1940 with assistance from the federal Works Projects Administration under the co-sponsorship of Mayor F. H. LaGuardia and the American Museum of Natural History. Three hundred and thirty copies of this Catalogue were printed, each bound in thirty loose-leaf ledgers containing about 1,200 pages apiece; over 200 subscribers now possess the work and receive the issues of supplementary sheets. The present staff, maintained by generous grants from oil companies, comprises ten permanent and two temporary members. M. Lys (France) then outlined his project to reproduce unpublished plates of foraminifera

prepared and annotated early last century by Alcide d'Orbigny. To enable the collection of all primary illustrations and descriptions of fossils into card-index form, S. H. Haughton (South Africa) advocated that the formation of a salaried bureau of the Union should be considered. J. Roger (France) spoke of the abstracting and card-index work now undertaken at the Centre d'Etudes et de Documentation paléontologiques and proposed that the Bureau of the Union should be at Paris. Discussion of these papers was followed by a Council decision to defer plans concerning the proposed bureau until the results became known of the International Geological Congress Council's deliberations on the possible formation of an International Geological Union with an approach to UNESCO. An observer was appointed to report on these negotiations.

The Union's second meeting, with Vice-President A. Morley Davies in the Chair, was devoted to discussing the uses of Foraminifera in Stratigraphy. A series of papers by T. Barnard, Miss I. Crespin (Australia), J. Cuvillier (France), L. M. Davies, H. J. Finlay (New Zealand), R. Grill (Austria), Mme Y. Gubler (France), H. Hiltermann (Germany), P. Marie (France), C. D. Ovey based on work by H. J. Finlay (New Zealand), and I. M. van der Vlerk (Netherlands), dealt with the application of foraminiferal studies to the stratigraphy of the Mesozoic and Cainozoic formations of Europe, Australia, the East Indies, India, and New Zealand.

The third meeting was concerned with the Nomenclature of Fossils, and Vice-President W. J. Jongmans (Netherlands) occupied the Chair. F. Hemming gave an historical account of the work of the International Commission on Zoological Nomenclature and outlined some of the changes in the code formulated at the 1948 International Zoological Congress held in Paris. He announced that a revised edition of the code, incorporating agreed interpretations, would shortly be issued, and replied to questions raised in a long and interesting discussion. A paper by L. Strauz (Hungary) followed, urging the need for quadrinominal nomenclature, particularly for Cainozoic mollusca, in view of the multiplicity of generic and specific names.

Three meetings of the Union's Council were held, and at the concluding meeting the following officers were elected :—

President . .	A. Morley Davies.
Vice-Presidents .	H. J. Harrington, B. F. Howell, W. J. Jongmans, A. Kryshtofovich, J. Piveteau, B. Sahni, C. J. Stubblefield, Y. C. Sun, V. Van Straelen.
Secretary . .	H. E. Vokes, Johns Hopkins University, Baltimore, Maryland, U.S.A.
Treasurer . .	Leif Størmer, University of Oslo, Norway.

Meetings on the Mineralogy and Geology of Clays

By D. M. C. MacEwan

A series of three meetings, under the general heading " Mineralogy and Geology of Clays ", was organized by the Clay Minerals Group of the Mineralogical Society, in collaboration with the International Geological Congress. The papers were grouped under four headings :—

1. The hydrous micas.
2. The kaolinitic minerals.
3. Physicochemical reactions of clay minerals.
4. Origin of clay minerals.

The first subject was introduced with a joint paper by R. E. Grim (U.S.A.) and W. F. Bradley (U.S.A.), presented by R. E. Grim. Optical, chemical, X-ray, and differential thermal data for a series of illites and related specimens were given, together with a discussion of the question of distinguishing between the two-layer (muscovite-like) and the one-layer (biotite-like) type of structure. The fact was stressed that the illites, as micas, for which the crystallization is " three dimensionally static " are to be distinguished from mixed-layer crystallizations of mica and montmorillonite (e.g. bravaisite and sarospatite). Two new occurrences of illitic material were reported in subsequent papers—at Ballater, Scotland (by R. C. Mackenzie, G. F. Walker, and R. L. Hart), and in Toscana, Italy (by C. Andreatta). Both these occurrences were considered to be of hydrothermal origin. These papers were followed by a discussion on the use of the terms " illite ", " hydromuscovite ", etc.

Under the second heading were grouped a series of papers from the Leeds workers who have been investigating the kaolinite minerals. A. L. Roberts and R. W. Grimshaw described the isolation, in relatively pure form, of the " fireclay type " of kaolinite mineral, which has previously been described by Roberts and by G. W. Brindley. The relationship of this mineral to kaolinite and metahalloysite was discussed. A. Westerman and A. L. Roberts described experiments on dry and wet grinding of kaolinite and halloysite, which showed a disappearance of crystallinity on prolonged dry grinding in accordance with Law's and Page's results. A general description of the relationship of the members of this group was given by Brindley.

The second meeting was devoted to a discussion of the third subject. S. Hénin (France) and S. Caillère (France) gave an account of experiments they have been carrying out on the transformability of clay minerals. The transformation of montmorillonite to a mica-like material by the action of KOH, and of montmorillonite to a chlorite, have been achieved, but not the reverse alterations of natural micas and chlorites.

A paper by J. W. Jordan, of the Mellon Institute, Pittsburgh, was presented by R. E. Grim. It described the alteration of bentonite to a condition in which it is compatible with liquid amines. Thixotropic organic gels have been prepared in this manner.

In the last session P. Gallitelli (Italy) described the formation in nature of a kaolinitic clay (containing some mica) from diabase. Experiments on the decomposition of diabase on a laboratory scale, by the percolation of CO_2-charged water, both at normal and elevated temperature and pressure, have shown the same minerals to be formed.

D. M. C. MacEwan described the formation in a Scottish soil derived from norite of a trioctahedral montmorillonite, by alteration of flakes of a biotitic mineral. The montmorillonite occurs as stable secondary aggregates, which are pseudomorphs after the original material, and account for the high base exchange capacity of the sand and silt.

J. E. Hemingway and G. W. Brindley described the occurrence of dickite as a replacement mineral in Middle Jurassic rocks of N.E. Yorkshire, an occurrence which they consider invalidates the view that dickite is necessarily of hydrothermal origin, and indicates its migration in solution.

All the papers gave rise to lively discussion, and the exchange of views was universally felt to be valuable. Considering the specialized nature of the subject-matter, the meetings were well attended. The Chairmen at the various meetings were as follows :—

First Session	.	Dr. G. W. Brindley (Chairman of the Clay Minerals Group) and Dr. S. Hénin (France).
Second Session	.	Professor R. E. Grim (U.S.A.) and Professor J. J. de Lange (Netherlands).
Third Session	.	Dr. W. Campbell Smith (President of the Mineralogical Society) and Dr. J. S. Hosking (Australia).

ANNOUNCEMENT

UNIVERSITY OF LONDON : SPECIAL UNIVERSITY LECTURES IN GEOLOGY

The Academic Registrar announces that two lectures will be given at University College (Gower Street, W.C. 1) by PROFESSOR G. DELÉPINE at 5.30 p.m. on 8th and 10th March, 1949. Admission free, without ticket.

Lecture 1 : Comparative Stratigraphy of the Carboniferous Marine Formations in N.W. Europe and Mediterranean Area.

Lecture 2 : Movements of the late Palaeozoic Seas—Devonian and Carboniferous—in W. Europe and N. Africa.

Crozzle and Hussle

By F. Wolverson Cope

Abstract

Description of an intraformational contorted shale in the Middle Coal Measures of the Potteries Coalfield. The contorted bed occurs immediately below the Winpenny Coal in thin argillaceous measures between thick sandstones. It shows strongly slickensided contacts, and consists of black carbonaceous shale, folded, sheared, and burnished. Deformation is ascribed to shearing stresses operating during folding. This shale is called "hussle" by the miners, whilst a similarly contorted, but non-carbonaceous, shale was termed "crozzle" by old miners of the Staffordshire–Derbyshire moors.

BREVITY has dictated the somewhat grotesque and possibly facetious looking title for this article dealing with certain intraformational contorted rocks which occur at several horizons in the Upper Carboniferous of North Staffordshire. Both crozzle and hussle are terms which have been borrowed from the old miners' terminology still considerably used in that area, and there is much to be said for the retention of one or both words as concise descriptive terms.

It is perhaps both interesting and of some significance that such special terms should, in the past, have been coined for intraformational contorted argillaceous rocks in an area showing some intensity of folding like the North Staffordshire coalfields, whereas no equivalent terms appear to have been used in the relatively unfolded but equally long-worked South Lancashire Coalfield.

The Millstone Grit and Lower Coal Measures of the Southern Pennines area consist of a rhythmic or cyclic sequence of sandstone or grit, seat-earth, coal, marine shale, and non-marine shale in ascending order, but it is only in the Millstone Grit that the marine phase of the cycle is normally represented. In the Lower Coal Measures, and to an even greater extent in the lower part of the Middle Coal Measures, the average cyclothem is incomplete. Nevertheless, the general result of this type of sedimentation is an alternating succession of thick sandstones or grits, and shales or mudstones of varying lithology.

In those regions where these formations have been compressed into moderately acute folds of considerable amplitude and wavelength, such as the Goyt Trough or Syncline to the west of Buxton, and the Potteries Syncline which includes the main coalfield of North Staffordshire, distinct beds of cleaved, brecciated, and contorted shale occur within the argillaceous formations. These beds ranging in thickness from about ½ inch to 3 feet, are under and overlain by normally bedded shales. These peculiar rocks have recently been studied on both the western and eastern limbs of the Goyt Syncline (Cope, 1946 A).

where it was demonstrated that the beds of contorted shale are remarkably constant in the horizons at which they occur, and that the contacts of the contorted beds, as they may briefly be termed, are normally clear-cut and plane, and either highly polished or slickensided in the direction of formational dip.

Each bed consists of non-carbonaceous blue or grey strongly fissile shale, and frequently exhibits numerous small, often acute, folds within the confines of its parallel contacts. The axial planes of such folds are inclined in the direction of formational dip, but at an angle in excess of the latter. The most conspicuous large scale structure in the contorted beds, however, consists of a succession of sigmoidally curved planes of shear. Each shear-plane is inclined in the direction of formational dip, though at a higher angle, and the curving ends merge into the strongly slickensided contacts of the contorted bed. Each surface of shear is markedly slickensided, grooved or fluted, in the direction of dip.

A tectonic origin was ascribed to the contorted beds of the Goyt Trough, the small folds being interpreted as drag folds and the shear planes as fracture cleavage. It was suggested that the contorted beds mark the main horizons of bedding-plane-slip, and are due to the concentration at the least competent horizons of the shearing stresses resolved from the regional folding of an alternating series of competent and incompetent strata.

The constancy of horizon of the contorted beds, at least over the limited area occupied by the outcrop of the Millstone Grit and Lower Coal Measures in the Goyt Trough, is a remarkable character which is to be linked with a parallel uniformity of lithology at any particular horizon over the same area.

The writer recently met an aged inhabitant of Orchard Common, Axe Edge (North Staffordshire portion) who stated that his grandfather worked in the old coal pits in that area. The coal there worked was that occurring a short distance below the *Gastrioceras cancellatum* marine band, and it appears that the well-marked contorted bed lying just above the marine band (Cope, 1946 A, p. 144) was well known to these old miners. They used the position of the contorted bed as an index to the depth to coal during the operation of shaft-sinking, maintaining that the coal was to be found 11 yards below the contorted bed. Owing to the peculiar structure of this particular bed (here 1 ft. 8 in. thick), the excavation of which by pick and spade would undoubtedly present considerable difficulty, they called it the " crozzly bed ", or the contorted shale composing it " crozzle ".

This constancy of horizon did, in the early stages of the Goyt Trough investigations, suggest that the contortions might be due to contemporaneous or pene-contemporaneous subaqueous sliding.

However, the markedly slickensided contacts of the contorted beds together with the precise relationship existing between the attitude of the internal structures and the dip and strike of the enclosing strata, clearly ruled out this possibility and pointed to a tectonic origin. Nevertheless, some critics have suggested that the material composing each contorted bed had originally slumped, and that subsequently, during the folding, the slickensiding and shearing had been superimposed. Such a theory of dual origin would perhaps be more difficult to prove than to disprove.

It is thought, however, that this possibility can be eliminated for the following reasons, amongst others. First, the drag folds or main contortions bear the same intimate relationship in their attitude, to the general dip and strike, as do the shear-planes, and consequently it is difficult to escape from the conclusion that both included structures are equally related to the folding.

Secondly, it is significant that many of the contorted beds occur closely associated with marine horizons. In several cases, a contorted bed rests directly upon the fossiliferous shales of a marine band. Of the European Upper Carboniferous sedimentation it can be asserted with some confidence that during those times marked by the formation of marine bands the bottom receiving the sediments was, to all intents and purposes, horizontal over very extensive areas. Frequently this substratum was a coal seam. Only by the existence of vast areas of quasi-horizontal sediments can truly widespread marine incursions giving remarkably uniform conditions be envisaged. One example, taken almost at random, will suffice for illustration. In the Goyt Trough the marine band characterized by *Gastrioceras cumbriense* Bisat, which lies within the dominantly argillaceous sediments between the Shining Tor Grit (Holcombe Brook Grit or Huddersfield White Rock) and the Danebower Grit (Rough Rock) has a bed of contorted shale resting directly upon it. The *G. cumbriense* marine incursion was so widespread, and apparently of such strict contemporaneity, that the surface of the sediments over which this incursion took place must have been horizontal. After the deposition of a thickness of marine mud and organic remains sufficient to produce, after compaction 2 or 3 inches of shale, the thickness shown by this band throughout the Southern Pennines, it is most unlikely that the upper limit of sediment could have departed from a quasi-horizontal position. Under such a relatively stable and uniform environment, subaqueous sliding of the immediately succeeding sediments could not have been initiated.

In the Goyt Trough area it is difficult to study or compute the relative amount of bedding-plane-slip which may have occurred at various horizons during the folding of an argillaceous formation separating two thick grits. In the shale formation between any two

grits, however, at least one contorted bed is present and this would appear to mark the horizon of the major bedding-plane-slip.

In the further example, described below, from the Middle Coal Measures of the Potteries Coalfield, the competent members are close together, the whole section is clearly and frequently exhibited in underground exposures, both on dip and strike faces and in the roof of the workings, and the selection of horizon at which major bedding-plane-slip occurred is therefore of considerable interest.

A Contorted Bed in the Middle Coal Measures of North Staffordshire

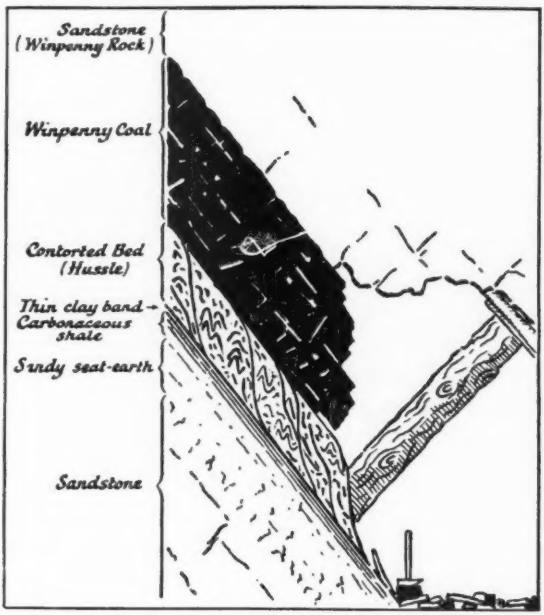
In the Biddulph, or northern, area of the Potteries Coalfield, the King Coal has been adopted, on palaeontological and stratigraphical grounds, as the base of the Middle Coal Measures (Cope, 1946 B, p. 84). Some 500 feet above the King is a good workable seam known as the Winpenny. This part of the Coal Measures succession includes a number of fairly thick sandstones. The Winpenny lies immediately below a thick sandstone (Winpenny Rock), and rests upon a few feet of shale and seat-earth which surmount a lower sandstone.

In the vicinity of Biddulph, the Potteries Syncline is a distinctly asymmetric fold with considerable amplitude and appreciable southerly pitch. The measures on the steeper western limb dip towards the east-south-east at an angle averaging 50°. Situated on this western limb and about one mile to the west of Biddulph village is the Hayhill (Winpenny) Colliery of the North Midland Coal Company. Here the Winpenny Coal is worked by means of a footrail or day-eye, which comprises a haulage road driven in the coal, dipping at 55°, from the outcrop and from which working levels are driven off on each side. Working proceeds very much on the lines of stoping in a metalliferous vein. The main haulage level now lies at a considerable distance from the outcrop. Owing to the high dip and relative thinness of the coal (2 ft. 9 in. to 3 ft.), the mine roads and working places show extensive sections of the coal and the measures lying immediately above and below.

The section depicted in Text-fig. 1 was measured in one of the higher levels of the mine and may be taken as typical.

The lowest bed exposed is a fairly massive grey sandstone with a ganister-like top containing *Stigmaria* sp. The upper surface of this is somewhat irregular, and on to it is welded a rather hard dark grey sandy seat-earth about 1 ft. thick, containing a great deal of carbonaceous material. The seat-earth passes upwards almost imperceptibly into a finely laminated highly carbonaceous black shale some 6 inches thick. This shale, which is rather greasy to the touch, contains *Sigillaria* spp. and numerous large stigmarian roots. Its

laminae are quite undisturbed, but its upper surface exhibits an almost mirror-like polish and shows slickensides running in the direction of the dip of the beds. Resting upon this very conspicuous polished bedding surface is a 1 in. band of soft grey clay. The succeeding bed is of finely laminated black carbonaceous shale, similar to the black shale just above the seat-earth in general lithology, but showing most intricate folding and shearing. In North Staffordshire this type



TEXT-FIG. 1.—Sketch of contorted bed beneath coal seam at Hayhill Colliery, near Biddulph, North Staffordshire.

of shale is known as *hussle*. This bed of hussle is 1 ft. 6 in. in thickness, and both its upper and lower contacts are beautifully polished and slickensided, the striations running in the direction of regional dip. Throughout the mine this bed shows extraordinarily perfect examples of small sub-acute folds, frequently only an inch or so in amplitude and wavelength. Without known exception the axial planes of these folds are inclined in the direction of stratal dip. In addition the bed is broken by numerous sigmoidally curved shear-planes which are strongly grooved and striated and dip in the direction of stratal dip but at an angle higher than the latter.

The (upper) contact of the contorted bed with the Winpenny Coal is conspicuously polished and slickensided in the direction of dip, and

considerable bedding-plane-slip has obviously occurred at this horizon. The seam itself is 2 ft. 10 in. thick and yields a good proportion of fairly large coal. The coal is succeeded by the Winpenny Rock which is a rather massive fine-grained sandstone, and the coal-sandstone contact is a closely welded one, no evidence of differential movement between the sandstone and coal being obtainable. In point of fact, it can be said that no slip has taken place at this horizon, for the sandstone-coal contact is slightly irregular, the sandstone descending to fill original shallow depressions in the top of the coal. There is no suggestion of a plane of movement within the coal at or below the base of these irregularities.

It would appear, therefore, that during folding the coal moved as though it were a corporate part of the overlying sandstone formation. There was, however, a distinct decrease of competence across the coal-hussle junction ; in fact, this was a junction between a higher competent and a lower incompetent formation, so that considerable bedding-plane-slip occurred there.

The basal sandstone also behaved as a competent bed during folding and carried with it the succeeding beds of gradually diminishing competence up to the thin clay band. These two groups of beds moved relatively in opposing directions, so that the 1 ft. 6 in. bed of hussle was subjected to a shearing couple. In this way the mirror-like and slickensided contacts and the small internal structures of the bed were produced.

In its general structure and in its relationships to the including strata this contorted bed is identical with those of the Goyt Trough. Whereas the contorted beds of the Goyt Trough consist of non-carbonaceous blue-grey shale, this contorted bed in the Middle Coal Measures is composed of highly carbonaceous shale. In each case, however, the shale is perhaps the most incompetent rock in its respective sequence.

The term hussle is still used extensively in North Staffordshire mines. It is applied to a rather greasy highly carbonaceous closely laminated shale or bass normally occurring in close association with coal seams. At least, that would appear to represent its current usage. It is most likely, however, that its original connotation was that given by Stobbs (1916), who defines hussel, hussle, or hustle as a highly slickensided carbonaceous shale (2 feet to 5 feet thick) which overlies the Bullhurst Seam [1] on the western side of the Potteries Coalfield. Unfortunately, the Bullhurst Coal is not now worked in the intensely disturbed Western Anticlinal area, so that this horizon is no longer open for examination.

[1] The Bullhurst Coal is usually about 60 feet stratigraphically above the Winpenny, the intervening strata being mainly sandstone (Winpenny Rock).

A contorted bed, or at least an horizon on which considerable bedding-plane-slip has occurred, could well have been predicted above the Bullhurst in the northern part of the Western Anticline. There, the Bullhurst Coal attains an abnormal thickness, 30 feet and over being not at all uncommon (Cowcill, 1928). The coal is surmounted by a small thickness of shales which are succeeded by a strong sandstone, and the hussle of Stobbs lies at the base of the shales.

In this connection, the writer has recently observed a contorted bed (of hussle) above the Alex Coal on an opencast coal site at Harewood Hall, near Cheadle (Staffs). The Alex Coal of Cheadle has been correlated with the Bullhurst Coal of the Potteries Coalfield (Cope, 1946 B, p. 85).

The writer is indebted to Mr. W. Owen-Jones, of the North Midland Coal Company, for facilities so readily provided during the examination of the workings at the Hayhill Colliery.

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Zones of Progressive Regional Metamorphism in the Moine Schists of the Western Highlands of Scotland

By W. Q. Kennedy

Abstract

The Moine Schists of Western Inverness-shire and North-West Argyll show a progressive increase in metamorphism when traced from the outcrop of the Moine Thrust-plane eastwards towards the central area of regional injection and migmatitization. It is possible to distinguish four zones of progressive metamorphism characterized by the development of distinctive mineral assemblages in the very subordinate, but widely distributed and highly distinctive calc-silicate granulites. The easterly increase in grade is attributed to the thermal effect of the great injection complexes, and it is suggested that the Torridonian, the Tarskavaig Moine Schists, and the Moine Schists proper merely represent successive stages in the regional metamorphism of one formation.

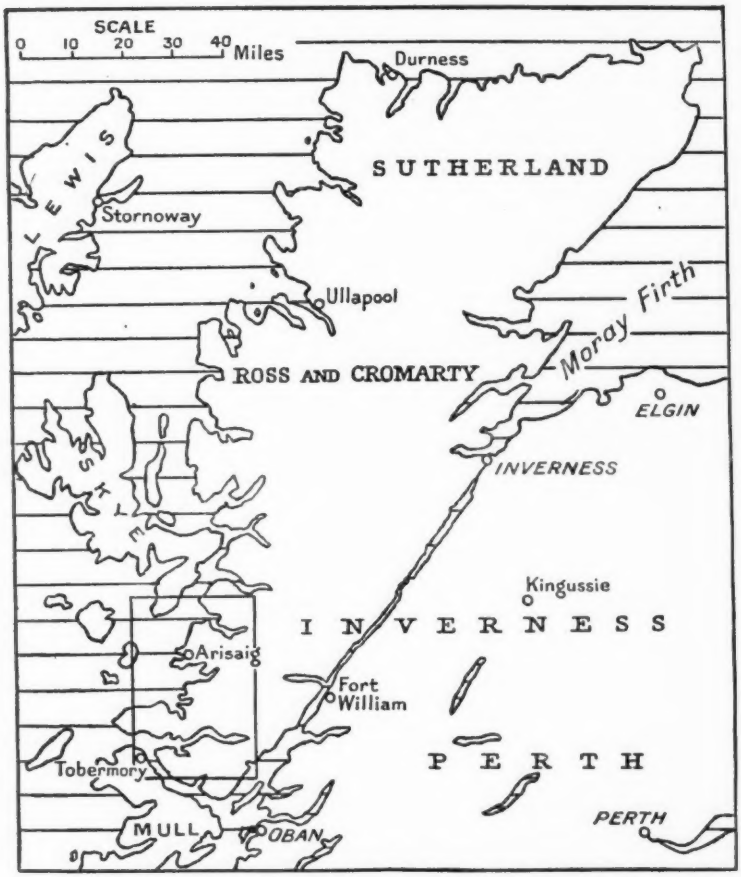
Introduction

THROUGHOUT Western Inverness-shire and North-West Argyll, the Schists of the Moine Series, which occupy most of the region between Loch Hourn and the Sound of Mull (Sheets 52 and 61 of the Geological Survey, 1-in. to the mile map of Scotland ; see maps, Text-figs. 1 and 4), show a marked progressive increase in metamorphism when traced from the coastal districts eastward towards the interior of the country. This effect appears to be related to two major geological features of the region : (1) the proximity of the Moine thrust which outcrops in the Sleat peninsula of Skye immediately to the west, and (2) the highly injected state of the schists throughout the eastern part of the region. It is a matter of considerable interest, therefore, to examine these relationships in somewhat greater detail and to attempt to assess their possible significance in respect to the structural evolution of the region as a whole.

The first step involves a more detailed study of the metamorphic variation, and for this purpose it is proposed to utilize the methods initiated by Barrow (1893, 1912) more than fifty years ago, and subsequently employed by Goldschmidt (1915), Tilley (1925), Vogt (1927), Barth (1936), and others, whereby the grade of the rocks is expressed in terms of the critical index minerals which develop successively in rocks of appropriate bulk composition under conditions of advancing metamorphism. In this connection, however, the Moine Schists present certain difficulties :—

1. The rocks are predominantly siliceous types, representing metamorphosed feldspathic sandstones, and beyond a certain point tend to show no further mineralogical response to rising temperature.
2. The more sensitive pelitic schists, to which Barrow's zonal indices (chlorite, biotite, garnet, kyanite, and sillimanite) could be applied,

are subordinate or localized in their distribution, and may be entirely absent throughout wide areas. They show, moreover, an incomplete metamorphic succession in that, although the *garnet* and *sillimanite zones* are fully developed, the *kyanite zone* as such cannot be distinguished owing to the virtually complete suppression of the typomorphic index mineral *kyanite*.



TEXT-FIG. 1.—Index Map. Area of Text-fig. 4 outlined.

3. Throughout wide areas the metamorphic grade of the rocks falls within the *garnet zone* as defined in normal pelitic schists, and this zone, as Harker (1932, p. 224) has pointed out, is in any case a broad one, so that "from the first appearance of garnet a considerable further rise of temperature must take place before the appearance of any new mineral which would serve as an index to a new zone". Its width is still further increased, moreover, by the non-development of kyanite and in effect the "garnet zone" may extend right up to the sillimanite isograd. Garnet is consequently

insufficiently sensitive as an index of grade within the particular temperature ranges concerned.

For the purposes of the present paper, therefore, it is proposed to base the zonal succession on the very subordinate but rather sensitive and widely distributed, semi-calcareous, calc-silicate granulites which occur in all the typical Moine areas of Scotland, and have been regarded by Flett (1923, p. 55) as diagnostic members of the Series as a whole.

Nature and Occurrence of Calc-Silicate Granulites in the Moine Series

The rocks in question are very distinctive types which occur solely as sporadic narrow bands and lenticles, up to an inch or two in thickness, associated with the normal psammitic and striped semi-pelitic schists of the Moine Series. They are easily recognized in the field on account of their mode of occurrence,[1] dense compact nature, pale colour (grey, white, or light green), and the presence of rather characteristic, small cinnamon-coloured garnets. Flett, who has studied typical members of the group from other parts of Scotland, considers that they must represent metamorphosed, somewhat argillaceous, calcareous sandstones (Flett, 1923, p. 55), and this view is confirmed by the presence of comparatively unaltered representatives among the low-grade (early *biotite-zone*) Tarskavaig Moine Schists of the Sleat peninsula of Skye. Similar calcareous (and somewhat argillaceous) ribs and lenticles, with identical relations to the enclosing rocks, are also found in the Loch na Dal beds of the Torridonian and provide suggestive evidence as to the Torridonian age of the Moine Schists.[2]

Within the Morar area at least, the calc-silicate granulites possess a certain stratigraphical significance and appear to be confined to the Upper Psammitic, Upper Striped, and Garnetiferous Pelitic Groups of the Moine succession (Richey and Kennedy, 1939, p. 29). They have not so far been proved definitely to occur in the Lower Psammitic or Lower Striped Schists, but this limitation is of small moment as the former divisions comprise by far the greater part of the Moine

[1] It is worthy of note that the calc-silicate bands do not normally occur in contact with pelitic rocks but are mainly localized along the centres of psammitic ribs interbedded with the striped pelitic and semi-pelitic schists.

[2] The calcareous ribs and lenticles in the Loch na Dal beds of the Torridonian are quite unaltered and still retain their original clastic structure. They are seen to consist essentially of angular grains of quartz and feldspar, together with shreds of chlorite and chloritized biotite, sericite, and rather abundant carbonate. The latter occurs either as a constituent of the base or in the form of tiny veins which intersect the rock in all directions. The feldspar was found to be predominantly albite in all the cases examined.

succession and are, moreover, widely distributed throughout the area as a result of folding.

Progressive Metamorphism of the Rocks

The mineralogical characters of the calc-silicate granulites from the area under consideration vary according to locality and in relationship to the progressive easterly increase in metamorphism which characterizes the region as a whole. Various parageneses have been recognized and are set out in Table I below. Analyses of typical representatives together with certain other analyses for comparison are given in Table II.

TABLE I

Parageneses of the Calc-Silicate Granulites in the Moine Series

	1			2	3	4
	a	b	c			
Quartz . .	+	+	+	+	+	+
Calcite . .	+	+				
Zoisite . .	+	+	+	+		
Acid Plagioclase .	+	+	+	+		
Bytownite . .					+	+
Biotite . .	+	+	+			
Hornblende . .		+		+	+	
Pyroxene . .						+
Garnet . .	+	+	+	+	+	+

The rocks in all cases consist essentially of quartz, together with garnet, a lime-silicate and one, or in certain transitional types, two ferromagnesian minerals. Acid plagioclase occurs only in the zoisite-bearing assemblages where it forms an important constituent of the ground mass mosaic.

Quartz and garnet are ubiquitous constituents and are present in all assemblages irrespective of grade. The garnet is the common red variety (almandine), but presumably contains a certain prop rtion of grossularite molecule as Barth (1936, p. 788) has shown to be the case in similar rocks from Dutchess County, New York. It forms poikiloblastic crystals which in the lower grades of metamorphism tend to develop crystal boundaries, but in the higher grades become smeared out into irregular streaks.

TABLE II

ANALYSES OF CALC-SILICATE ROCKS

	1	2	A	B	3
SiO_2 .	62·73	62·55	59·25	71·87	73·51
Al_2O_3 .	16·69	15·75	13·30	12·75	12·21
Fe_2O_3 .	0·42	1·56	0·84	0·29	0·44
FeO .	3·02	3·26	4·71	4·25	2·05
MgO .	1·09	2·88	4·20	1·07	0·59
CaO .	8·86	9·39	11·37	7·08	9·52
Na_2O .	2·88	0·93	1·73	0·33	0·21
K_2O .	0·90	1·54	2·42	0·06	0·05
H_2O+ .	0·94	0·64	0·73	0·55	0·27
H_2O- .	0·10	0·15	0·09	0·05	0·06
TiO_2 .	0·67	0·79	0·75	1·31	0·54
P_2O_5 .	0·31	0·30	0·18	0·05	0·11
MnO .	0·29	0·28	0·08	0·43	0·44
CO_2 .	0·98	tr.	0·13	n.d.	0·06
Rest .	—	0·09	0·14	—	0·02
Total .	99·90	100·11		100·10	100·08

1. Calc-zoisite-biotite-garnet granulite; (calc-silicate band) in Upper Striped Group of Moine Series, Shore N.E. side of Mallaig Harbour, Inverness-shire. C. O. Harvey, analyst. Average analysis of twenty individual bands.
2. Zoisite-hornblende granulite in Moine Series, 3/4 ml. S.W. of Glen Calvie Lodge, Ross-shire. W. Pollard, analyst, quoted from the "Geology of Ben Wyvis, etc." (Sheet 93), *Mem. Geol. Survey*, 1912, p. 45.

A. Calc-silicate gneiss, Almaaskroken, Norway. A. Röer, analyst. Quoted from V. M. Goldschmidt, "Die Kalksilikatgneise und Kalksilikatglimmerschiefer des Trondhjem-Gebiets," *Vidensk. Skr. I., Mat.-Naturv. Klasse.*, 1915, No. 10, p. 15.

B. Lime-silicate schist (hornblende-anorthite-garnet), Dutchess County, New York. E. Kluver, analyst. Quoted from T. Barth, "Structural and Petrological Studies in Dutchess County, New York, II. Petrology and Metamorphism of the Palaezoic Rocks." *Bull. Geol. Soc. Am.*, vol. 47, 1936, p. 813.

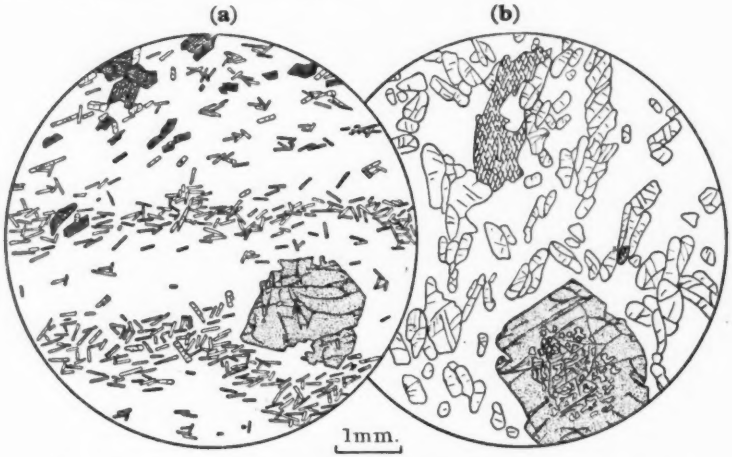
3. Pyroxene-anorthite granulite; calc-silicate band in Moine Series, Moidart district, 100 yards S. 20° W. of Dalilea Mica Prospect and 1,630 yards E. 10° S. of General Ross's Cairn. G. A. Sergeant, analyst.

The lime-silicate is either zoisite or anorthite, depending on the conditions of metamorphism; the transition from one to the other being controlled by the following reaction :—

$$2 \text{ zoisite} = 3 \text{ anorthite} + Ca(OH)_2$$

Zoisite is stable at the lower temperatures and is consistently a β variety with normal greyish interference colours and small optic axial angle. It forms either stout prismatic crystals (Text-fig. 2 (*b*)) or swarms of long thin needles (Text-fig. 2 (*a*)), which latter mode of occurrence is quite typical of the Group I assemblages (Table I), and could even be employed as a diagnostic feature of grade. Other

members of the clinozoisite-epidote group are not formed during the progressive metamorphism, but are developed locally in the high-grade assemblages where they result from retrograde reaction. *Anorthite* is confined to the high-temperature end of the metamorphic series and is present in the form of *bytownite* with approximately 85 to 90 per cent anorthite molecule (Text-fig. 3). There is no indication of gradual and progressive increase in the anorthite content of the plagioclase feldspar with advancing metamorphism, but on the contrary, the transition from albite and zoisite-bearing assemblages, on the one hand, to bytownite-bearing assemblages, on the other, appears to take place abruptly at the appropriate temperature. Potash feldspar has not been identified definitely in any of the rocks and the rôle of potassium remains obscure.



TEXT-FIG. 2.—Zoisite granulites from the Moine Series of Morar :
(*a*) Garnetiferous zoisite-biotite granulite.
(*b*) Garnetiferous zoisite-hornblende granulite.

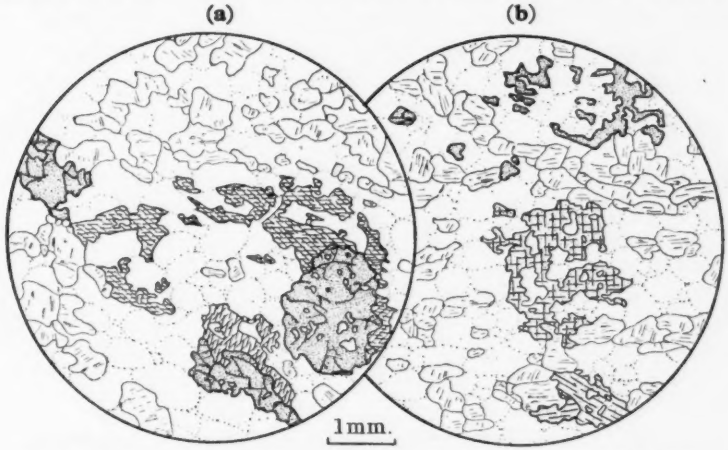
Under different conditions of metamorphism the stable ferromagnesian mineral may be represented either by biotite, hornblende, or pyroxene. The *biotite* is a normal reddish-brown variety and is confined to the Group 1 assemblages of Table I. *Hornblende* is stable over a considerable range of temperature and is characteristic of the intermediate stages of metamorphism. It is typically a distinctive, greyish-green, only slightly pleochroic type and forms rather large, irregular, spongy crystals much penetrated by the quartz of the groundmass mosaic. In addition, bright-green, highly-pleochroic, actinolitic hornblende is found in certain of the pyroxene-bearing granulites and represents a product of retrograde reaction. Colourless, apparently highly aluminous, pyroxene is confined entirely to the high-temperature assemblages and may, as pointed out above, revert to acicular, actinolitic hornblende as a result of retrograde change.

Sphene, apatite, zircon, and magnetite are ubiquitous constituents.

The structure of the rocks is granulitic or finely granoblastic, and

it is interesting to note that the grain size shows a progressive increase with advancing metamorphism. This is marked by an increase in the average diameter of quartz individuals in the ground mass mosaic, from 0·1 mm. in the Grade 1 assemblages of Table I to approximately 0·7 mm. in the Grade 4 bytownite-pyroxene-bearing types, and must involve suppression of the majority of the quartz grains and enlargement and progressive growth of a very small minority. The mechanism of the process when fully investigated should, therefore, prove to have an important bearing on the metamorphic evolution of the rocks.

It is apparent from the petrological and chemical characters of the calc-silicate granulites, that they belong to a well-defined *isochemical* series and that the differences in mineralogical composition are due



TEXT-FIG. 3.—Bytownite-granulites from the Moine Series of Morar :
(*a*) Garnetiferous bytownite-hornblende granulite.
(*b*) Garnetiferous bytownite-pyroxene granulite.

directly to differences in metamorphic environment. The observed parageneses consequently represent successive stages in the progressive metamorphism of the rocks. Consideration of the data in Table I shows, moreover, that the calc-silicate granulites from the area fall naturally into four well-defined groups or *facies* characterized by the following stable and critical mineral associations :—

Group 1	. garnet-zoisite-acid plagioclase-biotite	
	(*biotite* + *calcite* (*zoisite*) → *hornblende*)	Reaction
Group 2	. garnet-zoisite-acid plagioclase-hornblende	
	(2 *zoisite* → 3 *anorthite* + $Ca(OH)_2$)	Reaction
Group 3	. garnet-anorthite (bytownite)-hornblende	
	(*hornblende* → 4 *pyroxene*)	Reaction
Group 4	. garnet-anorthite (bytownite)-pyroxene	

These can be correlated with Eskola's standard facies as follows :—

Standard Facies. (Eskola)	*Facies of Calc-silicate Granulites.*
Epidote-amphibolite facies . .	Group 1 (Table I)
	„ 2 („)
Amphibolite facies	„ 3 („)
Pyroxene-hornfels facies . . .	„ 4 („)

It may be pointed out with regard to the equilibrium relationships of the rocks, that the presence of pyroxene would seem to depend not only on temperature, but also on an increase in the $\frac{CaO}{MgO}$ ratio. That such an increase has actually taken place in the case of the pyroxene-bearing assemblages may be seen from the analyses (1 and 3) in Table II where these rocks, when compared with the assemblages of lower grade, show a decrease in alkali content and a concomitant increase in the $\frac{CaO}{MgO}$ ratio. The distribution, mode of occurrence and field relationships of the calc-silicate granulites indicate that the rocks, in all cases, belong to a single isochemical series and must have been derived from essentially the same type of original material. The compositional differences are thus confined to the region of highest metamorphism and therefore the significant variations in certain chemical constituents must be attributed to actual change in the bulk composition of the rocks, effected during the process of metamorphism in the attainment of mineralogical equilibrium.

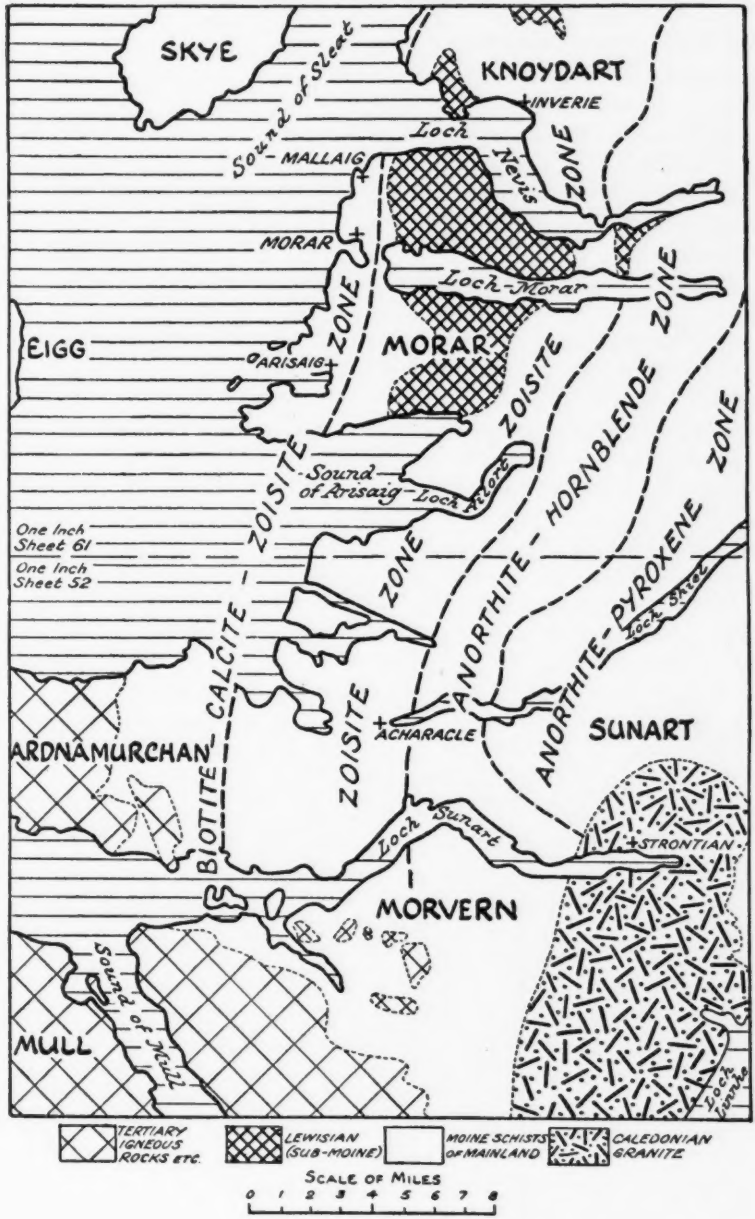
Zonal Relationships of the Moine Series Based on the Progressive Metamorphism of the Calc-Silicate Granulites

On the basis of the critical reactions, outlined above, it is possible to divide the region into a succession of metamorphic zones, each of which covers the pressure-temperature limits of one of the four mineral facies (see Zonal Map, Text-fig. 4). The zonal boundaries can be drawn with considerable precision, and it is found that the transition from one facies to another takes place abruptly, usually within a few hundred feet. Assemblages transitional between two different facies are consequently of highly restricted occurrence.

The various zones can be designated according to the leading (index) minerals or critical phases of each facies, and the following can be recognized from east to west :—

(1) Zoisite-(calcite-)biotite zone
(2) Zoisite zone
(3) Anorthite-hornblende zone
(4) Anorthite-pyroxene zone

MAP OF METAMORPHIC ZONES IN WESTERN INVERNESS-SHIRE AND N.W. ARGYLL



TEXT-FIG. 4.

This corresponds to a progressive easterly increase in metamorphic grade.

In general the zonal boundaries conform with the regional strike of the rocks, but the metamorphic zones themselves are not symmetrically disposed with respect to major folds, such as the Morar anticline, nor are they apparently influenced by the presence of inliers of older rock. There is, consequently, no simple depth relationship between the metamorphic zones and the tectonic structure. On the other hand, it is significant that the isograde which marks the zoisite-anorthite transition coincides almost exactly with the observed western limit of regional injection, as Read (1931) has also recognized in Central Sutherland. To the west of this line the rocks are normal Moine schists which show straight bedding, and in general retain all the details of their original sedimentary structures. They show little or no evidence of additive metamorphism, and convey the impression of having been metamorphosed within the garnet zone without serious intergranular movement. The Moine schists to the east of the anorthite *isograd* are in a fundamentally different condition, and are represented by coarsely crystalline injection gneisses and migmatites. Complex flowage folding, and widespread development of "boudinage" structures are characteristic phenomena and indicate intense movement of the rocks in a semi-plastic condition. Within this zone, which extends northward, southward, and eastward far beyond the limits of the area under immediate consideration, the Moine schists have been subjected to intense lit-par-lit injection and permeation by granitic material.

The metamorphic zones run parallel to the edge of this great injection complex, and there can be little doubt that they owe their development to the heat transmitted outwards from the thermal focus.

Within the interior of the injection complex the normal pelitic schists of the Moine series have been converted into sillimanite-cordierite gneisses and it is possible to locate the position of the sillimanite *isograd* with considerable precision. It is found to conform fairly accurately with the calc-silicate granulite isothermal boundaries, and to lie a short distance to the west of the pyroxene *isograd.* This provides a basis for the metamorphic correlation of the pelitic schists and calc-silicate granulites shown in table on p. 53.

As in the case of the Moine Schists generally, kyanite does not develop in the pelitic rocks of the district, and, following garnet, the first new mineral to appear with advancing metamorphism is normally sillimanite. It is not possible, therefore, to effect a complete metamorphic correlation of the calc-silicate granulites and pelitic schists on the basis of local evidence. Barth (1936, pp. 823–4) has pointed out, however, that in Dutchess County, New York, garnetiferous anorthite-hornblende granulites of the type in question are

Metamorphic Condition of Moine Schists	Uninjected		Injected	
Mineralogical Reaction in Calc-Silicate Granulites	Zoisite ——————→ Anorthite			
	Biotite → Hornblende		Hornblende → Pyroxene	
Zones based on Calc-Silicate Granulites	Zoisite-(Calcite)-Biotite Zone	Zoisite Zone	Anorthite-Hornblende Zone	Anorthite-Pyroxene Zone
Equivalent Zones in Normal Pelitic Schists	*Garnet Zone*		(*Kyanite Zone*)	*Sillimanite Zone*
Variation in metamorphic Environment	Temp. increase——————→			

isofacial with kyanite schists, and anorthite-pyroxene granulites with sillimanite gneisses. It may be assumed, therefore, that the position of the missing kyanite-zone in the Moine Schists is indicated by the anorthite-hornblende assemblages.

These results are in essential agreement with those obtained by Goldschmidt from the Trondhjem region (Goldschmidt, 1915, pp. 5–8), where in the development of typical calc-silicate gneisses from the semi-calcareous members of the Lower Palaeozoic Gula Group, the following stages could be recognized :—

Biotite zone	No lime silicates found.	Quartz - muscovite - biotite - calcite phyllites.
Garnet zone (including kyanite and sillimanite zones of Barrow)	(*a*) Development of members of clinozoisite - epidote group + almandine garnet.	Garnetiferous epidote-biotite granulites.
	(*b*) Development of hornblende.	Garnetiferous epidote-hornblende granulites.
	(*c*) Development of plagioclase at the expense of clinozoisite-epidote.	Plagioclase-hornblende granulites.
	(*d*) Development of pyroxene-at the expense of hornblende.	Plagioclase-pyroxene granulites.

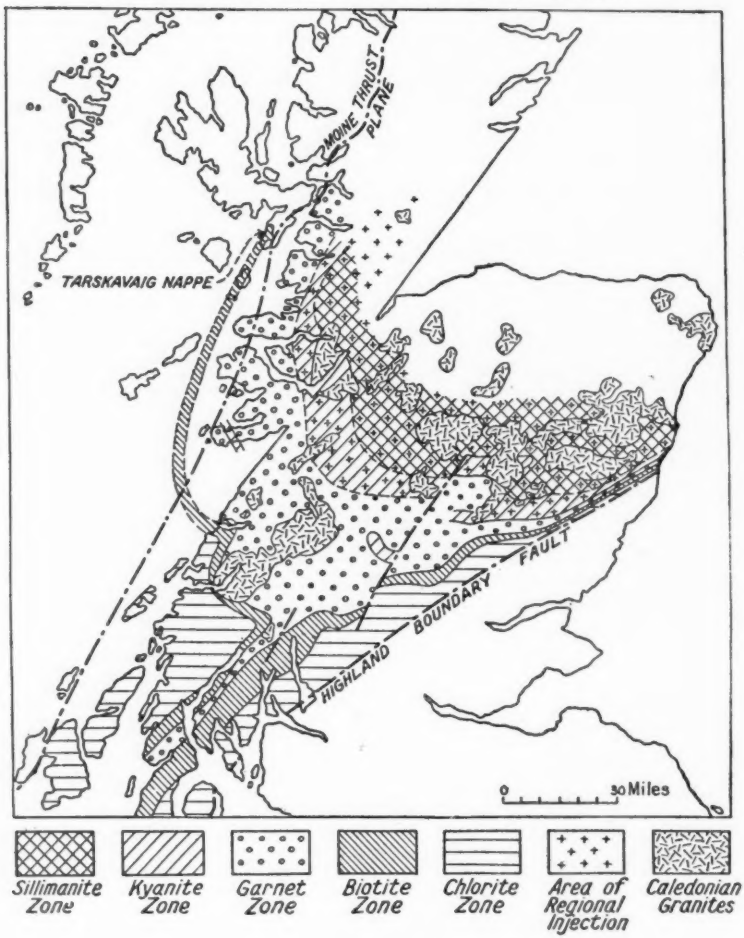
Despite significant differences in mineralogical and chemical composition this case provides an interesting parallel to the Moine Schists and confirms the usefulness of such semi-calcareous rocks as indices of grade in studies of progressive regional metamorphism.

Interpretation of the Results

In attempting to establish the significance of the zonal relationships discussed in the preceding sections, consideration must be given to

the fact that the area under investigation merely constitutes part of a much wider region of metamorphism which extends throughout the Highlands from the outcrop of the Moine Thrust Plane south-

GENERAL THERMAL MAP OF THE HIGHLANDS.



TEXT-FIG. 5.

eastwards to the Boundary Fault. Within this region the crystalline schists of the Moine and Dalradian Series show extreme variation with respect to metamorphic grade, as may be seen from the general zonal map (Text-fig. 5). In this map, which incorporates all the available zonal data, a correction has been made for the 65 miles of lateral displacement along the Great Glen Fault (Kennedy, 1946),

and the metamorphic zones appear in their true pre-fault relationships. The areas of regional injection and the main Caledonian granite masses are also shown.

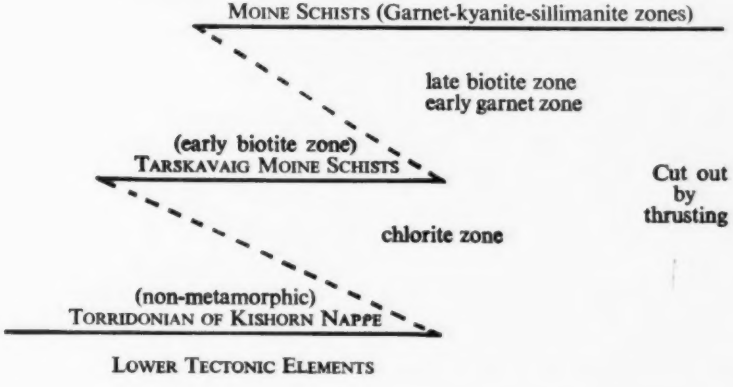
Consideration of the map leads to the recognition of the following significant features :—

(1) The inner (high temperature) kyanite and sillimanite *isograds* conform to the outer limit of central regional injection.

(2) The outer (low temperature) biotite and garnet *isograds*, on the other hand, are essentially parallel to the boundary fractures of the Highlands (Moine Thrust and Highland Boundary Fault).

These relationships can be readily explained if, following Barrow (1912), we attribute the metamorphism of the Highlands to the thermal influence of regional injection and relate the marginal decrease in metamorphism to distance from the thermal focus combined with fracture along the edges of the crystalline mass and outward thrusting in response to post-crystalline pressure.

Within the area with which the present paper has mainly been concerned, three formations, the Moine Series, the Tarskavaig Moine Series, and the Torridonian Series come together in South-East Skye, where they occupy different tectonic units, and form a series of superimposed nappes, piled one upon the other, in an ascending order of increasing metamorphism. The general structural and metamorphic relationships of these nappes are shown diagrammatically below :—



The contacts are thrust contacts, but despite the tectonic discordance one can clearly recognize that the westerly decrease in metamorphism of the Moine nappe (Text-fig. 4) continues in the lower tectonic elements. By straightening out the thrust tectonics we find that the three formations fall into line as follows :—

TORRIDONIAN OF KISHORN NAPPE	TARSKAVAIG MOINES			MOINE SCHISTS
non-metamorphic	chlorite zone	early biotite zone	late biotite zone ↓ early garnet zone	garnet zone ↓ kyanite zone ↓ sillimanite zone

The distinctions between the Torridonian, the Tarskavaig Moine Schists, and the Moine Schists proper are then seen to depend merely on an original westerly decrease of regional metamorphism affecting one great formation, combined with the fracturing and thrusting of the rocks along the edge of the crystalline area, and the consequent tectonic elimination of stages in the metamorphism.

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Types and figured specimens of Lower Palaeozoic Trilobites in the University Museum, Oxford

By James M. Edmonds

Abstract

Seventy specimens of trilobites are listed and reference is made to the works in which they were figured and described. Many of them were originally in private collections which have been deposited in the University Museum since the time of the publication. The specimens have been allotted numbers under a scheme of registration which it is intended should eventually incorporate the whole of the research and reference palaeontological collections under the care of the Professor of Geology at Oxford.

Introduction

An attempt is being made to catalogue the types and figured specimens in the collections of the Department of Geology at Oxford, as a first step towards the registration of the very large and valuable palaeontological collection which is under the care of the Professor of Geology and Palaeontology. It is hoped by this means to provide a record from which those engaged in palaeontological research can learn what material is available and, at the same time, to make the material more readily accessible for study.

As described in R. T. Gunther's *Early Science in Oxford*, the earliest collection of fossils in Oxford belonged to the Ashmolean Museum, and was founded on specimens presented by Martin Lister in 1685, and by Robert Plot in 1690. Edward Lhwyd, who followed Plot as Keeper of the Museum in 1691, was responsible for the first catalogue, but of the specimens listed in his *Lithophylacii Britannici Ichnographia* (1699) only two have been recognized as being still preserved in our present collections. Gunther also recorded his discovery in 1931 of a collection of fossils in Oriel College, which were labelled in the handwriting of Lhwyd and bore serial numbers, names, and localities agreeing with the details printed in the catalogue. He concluded, however, that they were duplicate specimens belonging to Richard Dyer, a friend of Lhwyd and a Fellow of Oriel.

The Collections have twice undergone removal since the eighteenth century, once in 1830, when William Buckland was Reader in Geology, and again in 1860, when his successor, John Phillips, was responsible for their transfer to the newly-built University Museum. At the same time they were greatly enriched by the private collections of these two Professors.

Soon after the removal in 1860, Phillips began the preparation of a catalogue of the fossils, being assisted in the work of their identification by Robert Etheridge, but the work is incomplete and lapsed after Phillips' death, and for three-quarters of a century no detailed record

appears to have been kept of the numerous collections, many of them of great interest, which have been added to the Museum by donation or purchase. There is, however, a manuscript list of types recognized by Miss M. Healey during the reorganization at the beginning of the present century, and this list has been of great value in the present work.

Once again, a transfer of the collections is taking place to a new Department of Geology, and Professor J. A. Douglas, recognizing the importance of seizing an opportunity which is not likely to occur again, has asked me to undertake the work of registration. The system which has been adopted is based on, and is very similar to, that in use at the Sedgwick Museum, Cambridge, and I am indebted to the Curator, Mr. A. G. Brighton, for his advice and explanation. Mr. W. E. Howarth, of the National Museum of Wales, kindly gave me information about the methods adopted in cataloguing at that Museum.

The first list to be completed is that of the Trilobites, and although it does not claim to be exhaustive, it is a record of what has so far been discovered, and may be of assistance to workers in this group by indicating the various collections which are available at Oxford for study. The method of presentation resembles that given by Dr. C. J. Stubblefield in *Summary of Progress of the Geological Survey for 1936—Part II*, pages 27–51. If the current name of a fossil differs from that originally given the new name is printed in heavy-faced type. Emendations and additions to the original notices of the stratigraphical horizon and locality of specimens are placed in square brackets, and the usual abbreviations are used : **H.** for Holotype, **L.** for Lectotype, and **S.** for Syntype. The registered number of the specimen is placed within square brackets at the bottom right-hand of each entry.

I wish to thank Professor J. A. Douglas for the opportunity to begin this work, and for his continued encouragement, and I would also like to express my indebtedness to Dr. C. J. Stubblefield, who kindly read through the list and directed me to literature which I had missed.

CAMBRIAN

Agnostus **cyclopyge** Tullberg 1880. Upper Lingula Flags.
Figured Lake 1906, pl. ii, fig. 21, p. 27 ; mentioned Lake 1946, p. 339. Species is genotype of **Pseudagnostus** Jaekel 1909.
White-leaved Oak, Malvern Hills, Herefordshire. [A1]

Bailiella lyelli (Hicks 1871), see under *Conocoryphe lyellii.*

Conocoryphe **lyellii** Hicks 1871. [Solva Beds, Middle Cambrian.]
Figured Hicks 1871, pl. xvi, fig. 6, p. 399. Species referred to **Bailiella** Matthew 1885, Resser 1936, p. 17 ; Lake 1940, p. 277.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. **S.** [A10]

? Ctenopyge bisulcata (Phillips 1848), see under *Olenus pauper*.

Ctenopyge teretifrons (Angelin 1854). Upper Lingula Flags.
Figured Lake 1913, pl. x, fig. 10, p. 88.
" Malvern," [? Herefordshire]. [A6]

Eodiscus punctatus (Salter 1864), see under *Microdiscus punctatus*.

Microdiscus **punctatus** Salter 1864. Menevian.
Figured Lake 1907, pl. iii, figs. 13, 17, 17a, p. 36. Species referred to **Eodiscus** Hartt MS. Walcott 1884, Howell 1925, p. 123 ; Lake 1946, p. 339.
fig. 13. Dwrrhyd, near Solva, Pembrokeshire. [A2]
fig. 17. ditto [A3a]
fig. 17a. ditto [A3b]

Olenus pauper Phillips 1871. Upper Cambrian.
Figured Phillips 1871, diagram xvii, fig. 4,[1] p. 68. Referred to ? *Sphaerophthalmus flagellifer* Angelin 1854, Groom 1902b, p. 103 ; to **? Ctenopyge bisulcata** (Phillips 1848), Lake 1913, p. 81.
South Malverns, [Herefordshire]. Phillips Coll. H. [A9]

Paradoxides harknessi Hicks 1871. [Solva Beds, Middle Cambrian.]
Counterpart of specimen (Sedgwick Mus. A1085) figured Hicks 1871, pl. xv, fig. 9, p. 399, and refigured Lake 1935, pl. xxvii, fig 3, p. 217.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. [A179]

Paradoxides sedgwicki (Hicks 1871), see under *Plutonia sedgwickii*.

Plutonia sedgwickii Hicks 1871. [Solva Beds, Middle Cambrian.]
Figured Hicks 1871, pl. xv, fig. 2, p. 399 ; referred to **Paradoxides sedgwicki,** Lake 1935, pl. xxxi, fig. 10, p. 221, where a wax cast (Sedgwick Mus. A1078) of an artificial intaglio of this specimen is figured.
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. S. [A173]

Plutonia sedgwickii Hicks 1871. [Solva Beds, Middle Cambrian.]
Counterpart of specimen (Sedgwick Mus. A1077) figured Hicks 1871, pl. xv, fig. 3, p. 399, and refigured Lake 1935, pl. xxxi, fig. 8, p. 221, where referred to **Paradoxides sedgwicki.**
Headland near Nun's Well, St. David's, Pembrokeshire. Hicks Coll. S. [A11]

Pseudagnostus cyclopyge (Tullberg 1880), see under *Agnostus cyclopyge*.

[1] Figure is reversed.

Sphaerophthalmus major Lake 1913. Upper Lingula Flags.
Figured Lake 1913, pl. viii, figs. 12, 13, p. 77.
fig. 12. Malvern Hills, Herefordshire. **S.** [A4]
fig. 13. ditto **S.** [A5]

TREMADOCIAN

Acanthopleurella grindrodi Groom 1902. Bronsil Shales, Tremadoc.
Figured Groom 1902a, text-figs. 2, 3, p. 70 ; refigured and referred to *Shumardia pusilla* (Sars 1835), Lake 1907, pl. iv, fig. 3, pp. 40, 42 ; opinion of Stubblefield and Raw given that Groom's name should stand, Lake 1946, p. 341. According to Groom 1902a, p. 70, specimen was referred to *Conophrys salopiensis* Callaway 1877, pp. 660, 667. **Genoholotype.**
Southern Malverns, [Herefordshire]. Grindrod Coll. **H.** [A7]

Acanthopleurella grindrodi Groom 1902. Bronsil Shales, Tremadoc.
Figured Groom 1902a, text-fig. 4, p. 70 ; see also references above.
Southern Malverns, [Herefordshire]. Grindrod Coll. **P.** [A8]

Asaphellus homfrayi (Salter 1866), see under *Asaphus homfrayi.*

Asaphus (*Isotelus ?*) **homfrayi** Salter 1866. Tremadoc Slates.
Counterpart of the specimen (Sedgwick Mus. A1266) figured Salter 1866a, pl. xxiv, fig. 6, p. 165, and Salter 1866b, pl. viii, fig. 11, p. 311. Species is the genotype of **Asaphellus** Callaway 1877.
Under the Garth, near Tremadoc, [Carnarvonshire]. Ash Coll. ex Homfray Coll. Counterpart of **S.** [A16]

Niobe homfrayi Salter (?). Bronsil Shales.
Figured Groom 1902b, text-fig. 31, p. 125. Lake 1942, p. 331, says " not *Niobe* (*Niobella*) *homfrayi* Salter ".
Southern Malverns, [Herefordshire]. ? Grindrod Coll. [A30]

Niobe (*Ptychocheilus*) ? sp. Bronsil Shales.
Figured Groom 1902b, text-fig. 30, p. 122. " Too poor for accurate determination ", according to Reed 1931, p. 471.
[South] Malvern[s, Herefordshire]. ? Phillips Coll. [A203]

Platypeltis sp., cf. *croftii* Callaway. Bronsil Shales.
Figured Groom 1902b, text-fig. 29, p. 122. Lake 1942, p. 315, says " cannot belong to this [*Platypeltis*] genus ".
White-leaved Oak, Malvern [Hills, Herefordshire]. ? Grindrod Coll. [A28]

Tomaculum problematicum Groom 1902. Bronsil Shales.
Figured Groom 1902b, text-figs. 32, 33, 34, 35, p. 126. **Genoholotype.**
fig. 32. [South] Malvern[s, Herefordshire]. ex G. E. Mackie Coll. **S.** [A34]

figs. 33, 34. [South] Malvern[s, Herefordshire]. Mackie Coll. S. [A35]
fig. 35. ditto ditto S. [A33]

ORDOVICIAN

Asaphus (*Basilicus ?*) **radiatus** (Salter 1846). [Ashgillian.]
Figured Salter 1866, pl. xviii, fig. 1, p. 157 ; referred to **Ptychocheilus** Nova'k 1883, Reed 1931, p. 465.
Berwyn Mountains, [Merioneth].[1] ex Blunt Coll. [B2]

Eohomalonotus quadratus (Hicks 1873), see under *Neseuretus quadratus*.

Neseuretus **quadratus** Hicks 1873. [Arenig.]
Figured Hicks 1873, pl. iii, figs. 12, 24, p. 45. Species referred to *Homalonotus* (*Brongniartia* sens. lato) Reed 1918, p. 319 = **Eohomalonotus** op. cit., p. 231.
fig. 12. Ramsay Island, or Tremanhire, St. David's, Pembrokeshire. Hicks Coll. S. [B9]
fig. 24. ditto ditto ? S. [B10]

Nieszkowskia unicus (Wyville Thomson 1857), see under *Staurocephalus ? unicus*.

Niobe **menapiensis** Hicks 1873. [Arenig.]
Figured Hicks 1873, pl. iv, figs. 3, 4, p. 46 ; referred to *Asaphellus* Callaway 1877, Brögger 1896, p. 61 ; to *Hemigyraspis* Raymond 1910, p. 41 ; to **Ogyginus ?** Raymond 1912, Reed 1931, p. 461.
fig. 3. St. David's, Pembrokeshire. Hicks Coll. S. [B6]
fig. 4. ditto ditto S. [B7]

Niobe solvensis Hicks 1873. Arenig.
Figured Hicks 1873, pl. iv, fig. 10, p. 47 ; referred to *Asaphellus* Callaway 1877, Brögger 1896, pp. 43, 47 ; to **Niobe (?)** Reed 1931, p. 471.
Ramsey Island or Tremanhire, St. David's, Pembrokeshire. Hicks Coll. S. [B8]

Ogyginus ? menapiensis (Hicks 1873), see under *Niobe menapiensis*.

Ptychocheilus radiatus (Salter 1846), see under *Asaphus* (*Basilicus ?*) *radiatus*.

Sphaerocoryphe thomsoni Reed 1906, see under (a) *Staurocephalus* (*?*) *unicus*, (b) *Staurocephalus* sp.

Staurocephalus (*?*) *unicus* (Wyville Thomson 1857). [Balclatchie Group.]
Figured Salter 1865, pl. vii, figs. 22a, 22b, 22c, p. 86 ; referred to *Cheirurus* (**Sphaerocoryphe**) **thomsoni** Reed 1906, p. 146.

[1] Note associated with specimen gives the locality as " N. Wales, probably near Bala or Corwen ".

Penwhapple Glen or Burn, Ayrshire. ex Wyville Thomson Coll. [probably composite from B4 and B5]

Staurocephalus (*?*) *unicus* (Wyville Thomson 1857). [Balclatchie Group.]

Figured Salter 1865, pl. vii, fig. 23, p. 86; referred to *Cheirurus* **(Nieszkowskia) unicus** (Wyville Thomson) Reed 1906, p. 142.

Penwhapple Glen or Burn, Ayrshire. ex Wyville Thomson Coll. [B3]

Staurocephalus sp. (*Staurocephalus nodulosus* Salter Ms.). Drummock Group.

Figured Salter 1865, pl. vii, fig. 25, p. 87. Should be referred to **Sphaerocoryphe thomsoni** Reed 1906.

Girvan, Ayrshire. ex Wyville Thomson Coll. [B1]

Ordovician of Peru

Asaphus sp. Llanvirnian.

Figured Douglas 1933, pl. xxix, fig. 7, p. 345.

Bed B, Yuscamayo River, Peru. Douglas Coll. [BU9]

? Homotelus sp. Llanvirnian.

Figured Douglas 1933, pl. xxviii, fig. 10, p. 345.

Bed C, Yanahurco River, Peru. Douglas Coll. [BU1]

Homotelus sp. Llanvirnian.

Figured Douglas 1933, pl. xxviii, figs. 11, 12, 13, 14, p. 344.

figs. 11, 12. Bed C, Yanahurco River, Peru. Douglas Coll [BU2]
fig. 13. ditto ditto [BU3]
fig. 14. ditto ditto [BU4]

Triarthrus aff. **fischeri** Billings emend. Bulman 1931. Llanvirnian.

Figured Douglas 1933, pl. xxix, fig. 6, p. 345.

Bed C, Yanahurco River, Peru. Douglas Coll. [BU8]

Triarthrus sp. Llanvirnian.

Figured Douglas 1933, pl. xxix, figs. 3, 4, 5, p. 345.

fig. 3. Bed A, Yuscamayo River, Peru. Douglas Coll. [BU5]
fig. 4. ditto ditto [BU6]
fig. 5. Bed B, Yuscamayo River, Peru. ditto [BU7]

Trinucleus sp. Llanvirnian.

Figured Douglas 1933, pl. xxix, fig. 8, p. 346.

Bed C, Yanahurco River, Peru. Douglas Coll. [BU10]

Silurian

Acaste downingiae (Murchison 1839) var., see under (a) *Phacops constrictus*, (b) *Phacops downingiae*.

Dalmanites nobilis (Thomas 1900), see under *Phacops* (*Dalmania*) *nobilis*.

Dalmanites vulgaris (Salter 1864), see under (a) *Phacops caudatus* var. α *vulgaris*. (b) *Phacops caudatus* var. β, *tuberculato-caudatus*.

Deiphon forbesi Barrande 1850. Wenlock Shale.
Figured Salter 1865, pl. vii, figs. 1a, 1b, 1c, 2, p. 88 ; referred to var. **barrandei** Whittard 1934, p. 513.
figs. 1a, 1b, 1c. " Malvern," [Herefordshire]. Grindrod Coll. [C19]
fig. 2. ditto ditto [C20]

Deiphon forbesi Barrande 1850 var. **barrandei** Whittard 1934. Wenlock Shale.
Figured Whittard 1934, pl. xvi, figs. 1, 4, p. 513.
fig. 1. West of the Malvern Hills, Herefordshire. Grindrod Coll. **H. of var.** [C21]
fig. 4. " Malvern," [Herefordshire]. ditto **P. of var.** [C22]

Encrinurus onniensis Whittard 1938. Upper Valentian.
Figured Whittard 1938, pl. iv, figs. 8, 9, 10, p. 118.
Onny River Section, near Cheney Longville, Shropshire. ex J. Plant Coll. **S.** [C1]

Heliocephalus coronatus (Thomas 1900), see under *Phacops* (*Dalmania*) *coronatus*.

Homalonotus (*Koenigia*) **knightii** Koenig 1825. Upper Ludlow.
Figured Salter 1865, pl. xii, figs. 7, 8, 8a, p. 119, and by him wrongly referred to sub-genus *Koenigia*, since this species is the genotype of **Homalonotus** Koenig 1825.
" Malvern," [Herefordshire]. Grindrod Coll. [C16]

Illaenus (Bumastus) barriensis (Murchison 1839). Woolhope Shales.
Figured Salter 1867, pl. xxvii, fig. 2 (upper figure), p. 203.
Malvern Tunnel [MS. label gives " Wyche Railway "], Herefordshire. Grindrod Coll. [C13]

Illaenus (Bumastus) barriensis (Murchison 1839). Wenlock Shale.
Figured Salter 1867, pl. xxvii, figs. 3, 5, p. 203.
fig. 3. Malvern Tunnel, Herefordshire. Grindrod Coll. [C14]
fig. 5. ditto ditto [C15]

Illaenus (*Dysplanus*) *bowmanni* Salter 1848. Lower Llandovery.
Figured Salter 1867, pl. xxx, fig. 6, p. 185 ; mentioned as " not *I. bowmanni* " by Reed 1904, p. 59 ; referred to **? Illaenus thomsoni** Salter 1851, Reed 1935, p. 16.
Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. [C6]

Illaenus (Bumastus) insignis Hall 1864. Wenlock Limestone.
Figures Salter 1867, pl. xxvii, figs. 6a, 6b, p. 207.
Ledbury, Herefordshire. Grindrod Coll. [C12]

Illaenus (Bumastus) maccallumi Salter 1867. Lower Llandovery.
Figured Salter 1867, pl. xxx, figs. 2, 3, p. 210.
fig. 2. Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. **S.** [C4]
fig. 3. ditto ditto **S.** [C5]

Illaenus (Dysplanus) nexilis Salter 1867. Lower Llandovery
Figured Salter 1867, pl. xxx, fig. 4, p. 190.
Mulloch or " Drummuck ", near Girvan, Ayrshire. ex Wyville Thomson Coll. **S.** [C2]

Illaenus (Dysplanus) thomsoni Salter 1851. Llandovery.
Figured Salter 1867, pl. xxx, fig. 8, p. 188. Species identification queried by Reed 1904, p. 70.
Mulloch, Girvan, Ayrshire. ex Wyville Thomson Coll. [C3]

Phacops caudatus (Brongniart 1822 *non* Brünnich 1731) var. α, *vulgaris.* Ludlow.
Figured Salter 1864, pl. iii, fig. 16, p. 51. Following Lindström 1885, p. 37, the species would be named **Dalmanites vulgaris** (Salter 1864) pending further revision of the material.
Ledbury, Herefordshire. ? ex J. W. Salter Coll. [C40]

Phacops **caudatus** (Brongniart 1822 non Brünnich 1781) var. β, **tuberculato-caudatus** Murchison. Lower Ludlow.
Figured Salter 1864, pl. iv, fig. 1, p. 53. Species referred to **Dalmanites vulgaris** (Salter 1864), Delo 1935b, p. 425.
Ledbury Tunnel, Herefordshire. Grindrod Coll. [possibly C11]

Phacops constrictus Salter 1864. Wenlock Shale.
Figured Salter 1864, pl. ii, figs. 13, 13a, 14, p. 27. Referred to **Acaste downingiae** (Murchison 1839) var. **constrictus.**
figs. 13, 13a. Malvern Tunnel, Herefordshire. Grindrod Coll. **S.** [C7]
fig. 14. ditto ditto **S.** [C8]

Phacops (*Dalmania*) **coronata** Thomas 1900. Wenlock Shale.
Figured Thomas 1900, pl. xxxv, figs. 1, 2, 3, p. 616. Referred to (probably) subgenus *Synphoria* Clarke 1900, Reed 1927, p. 343; to *Malvernia* Delo 1935a, p. 411, as **genoholotype** [1]; subsequently renamed **Heliocephalus** Delo 1936, p. 417, when the name *Malvernia* was found to be preoccupied.
fig. 1. Malvern Tunnel, Herefordshire. Grindrod Coll. **S.** [C34]
figs. 2, 3. ditto ditto **S.** [C35]

[1] Delo quotes Thomas' fig. 4 as lectotype of the genotype species. This figure is, however, composite, and either C34 or C35 must be substituted, preferably C35.

Phacops **downingiae** (Murchison 1839) Wenlock Limestone.
var. γ **inflatus.**

Figured Salter 1864, pl. ii, fig. 30, p. 28. The species **downingiae** is genotype of **Acaste** Goldfuss 1843.

Ledbury, Herefordshire. Grindrod Coll. [C9]

Phacops (*Dalmania*) **nobilis** Thomas 1900. Wenlock Shale.

Figured Thomas 1900, pl. xxxiv, figs. 1, 2, p. 617. The name *Dalmania* was considered invalid in trilobite nomenclature by Barrande 1852, R. and E. Richter 1931, p. 141, and Delo 1935b, and is replaced by **Dalmanites** Barrande 1852.

fig. 1. 1 mile east of Builth, 150 yards from bank of Wye, Brecknockshire. Grindrod Coll., ex " Mr. Jones Coll." **H.** [C24]

fig. 2. ditto ditto **H.** [C25]

The specimen C25 is the counterpart of C24.

Phacops (*Dalmania*) **nobilis** Thomas 1900. Wenlock Shale.

Figured Thomas 1900, text-fig. on p. 618 ; internal and external casts of eye. Referred to **Dalmanites,** as previous entry.

Same locality as C24, C25. [" Devil's Pitch " on MS. label.] Grindrod Coll. [C27, C26 counterpart]

Sphaerexochus mirus Beyrich 1845. Wenlock Shale.

Figured Salter 1864, pl. vi, fig. 3, p. 76.

Malvern Tunnel, Herefordshire. Grindrod Coll. [C23]

Staurocephalus murchisoni Barrande 1846. Wenlock Shale.

Figured Salter 1865, pl. vii, figs. 15a, 15b, 16, p. 84.

figs. 15a, 15b. " Malvern," [Herefordshire]. Grindrod Coll. [C17]

fig. 16.[1] ditto ditto [C18]

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[1] Figure is an enlargement.

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A Revised Terminology and Subdivision of the Middle Jurassic Rocks of Yorkshire

By J. E. HEMINGWAY

ABSTRACT

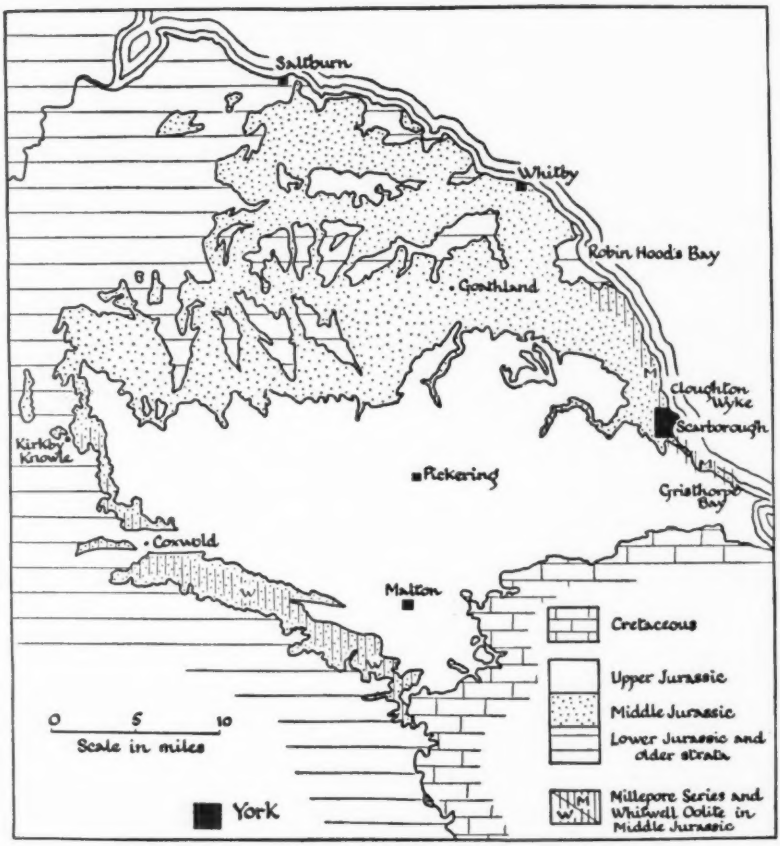
It is suggested (1) that the term " Estuarine Series ", as applied to the Middle Jurassic rocks of Yorkshire, should be abandoned and that " Deltaic Series " should be substituted ; (2) that the boundary between the lower and middle divisions of this series should be revised and that the persistent Eller Beck Bed should be substituted for that boundary in place of the wedging Millepore Series of the Scarborough district and its inland equivalent, the Whitwell Oolite.

ON the occasion of the visit of the International Congress to this country, it is fitting to reconsider the terminology and subdivision of the Middle Jurassic rocks of the Yorkshire basin, with a view to eliminating two inconsistencies.

After being known mainly in terms of their lithology from the time of William Smith, the current nomenclature and subdivision of these rocks was established during the official geological survey of East Yorkshire and adopted by the Survey in 1880 (Fox-Strangways, 1892, table opposite p. 22). It was first published, though not completely, in 1880, in *The Geology of the Oolitic and Cretaceous Rocks South of Scarborough* (first edition), followed in other sheet memoirs of this region and in the better-known compilation from them (Fox-Strangways, 1892). In these publications the Middle Jurassic rocks of Yorkshire were subdivided into Lower, Middle, and Upper Estuarine Series, separated by the Millepore Series (or Whitwell Oolite) and the Grey Limestone Series respectively and underlain by the Dogger (see table, p. 70). This subdivision was adopted in part from the succession established by earlier workers in this province.

The term Estuarine Series is now generally recognized as a misnomer. It was based on Fox-Strangways's interpretation of the conditions of sedimentation in N.E. Yorkshire at this time, which, he maintained, " formed part, either of the estuary of some large river, or possibly of a series of channels or straits between neighbouring islands " (p. 391). It is possible that in this terminology, Fox-Strangways was influenced by Morris's work in Lincolnshire (Morris, 1853). Despite the Survey interpretation, the deltaic character of these beds had been clearly recognized for some time. In 1868 Simpson recorded and appreciated the significance of the several thin but widespread coal seams, the patches of vertical *Equisetum*, and particularly " the shales and deposits of mud [which] have been cut and divided by strong currents of water, and beds of sand [which] have been deposited in the hollows. . . . All these phenomena are in strict accordance with

those presented in the deltas of rivers " (Simpson, 1868). Although Fox-Strangways's unfortunate terminology persisted, the deltaic origin of these beds was favoured (e.g. Kendall and Wroot, 1924). Most recently Black has conclusively demonstrated the deltaic origin of



TEXT-FIG. 1.—Sketch map showing the limited outcrop of the Millepore Series and the Whitwell Oolite in the Middle Jurassic rocks of N.E. Yorkshire and its unsatisfactory character as a dividing bed.

these rocks by tracing the sandstone-filled distributory channels which cut the more regularly bedded sediments and by relating these channels to the locally developed plant-beds (Black, 1928, 1929, 1934*a* and *b*).

In order to obviate the qualification and near-contradiction " so-called ", frequently affixed to the Estuarine Series and also to clarify future reference to the origin of this rock group, the writer urges that the term " Estuarine Series " should be abandoned and " Deltaic

Series " substituted. Attempts to give less committal areal or locality names to the subdivisions, other than the marine beds, have proved unsatisfactory because of the wide distribution of each and the difficulty of defining standard sequences which are both well-exposed and accessible.

A second alteration is also suggested here. The Geological Survey used the marine Millepore Series to separate the Lower from the Middle Estuarine Series. In this Fox-Strangways and his staff, working north-westwards up the Yorkshire coast, adopted for *regional* use a bed which had become well established by earlier and contemporary investigators as a convenient *local* divisional plane, centred mainly on Scarborough. This bed attains a thickness of 40 feet at Yons Nab, four miles S.E. of Scarborough, but it thins to the north-north-west and disappears near Robin Hood's Bay. As an effective boundary therefore it occupies only thirteen miles of coast line. Further, its inland equivalent, the Whitwell Oolite, though more widely distributed, also dies out near Kirkby Knowle, 33 miles north-west of the Market Weighton axis, the southern limit of the Yorkshire Jurassic basin. Thus, over an area of about 340 square miles, which includes by far the greater part of the outcrop of the Middle Jurassics of Yorkshire (400 square miles), the junction between the Lower and Middle " Estuarine " Series cannot be defined, with consequent confusion in terminology (Text-fig. 1). It is therefore suggested that this boundary should be revised, by using the Eller Beck Bed in preference to the Millepore Series.

The marine Eller Beck Bed, which occurs from 100 feet to 170 feet above the Dogger, was first recorded near Goathland during the official survey (Barrow, 1877) and was included in the Lower Estuarine Series. It outcrops in N.E. Yorkshire from near Cloughton to Brotton and Boosbeck near Saltburn and southwards down the western escarpment to Coxwold. Here it passes from a ferruginous to a calcareous facies, the Hydraulic Limestone, which continues south-eastwards to the Humber. It may also be traced round the several Cleveland inliers as a readily mapped horizon, and has been found by the writer to be more widely distributed than the Survey 1 in. maps indicate. It is undoubtedly persistent throughout the whole outcrop of the Middle Jurassic of Yorkshire.

On the grounds of convenience alone the claims of the Eller Beck Bed as a boundary between two parts of the Deltaic Series are clearly superior to those of the impersistent Millepore Series. Further, Professor T. M. Harris informs me and kindly allows me to state that in an examination of the plant spores in the fine-grained sediments of the Yorkshire Deltaic Series, marked breaks in the distribution of the several types occur at the Eller Beck Bed and the Grey Limestone

Series, but not at the Millepore Series. The case for revised subdivision therefore appears to be established. It is suggested that the Eller Beck Bed should be used to separate a reduced Lower Deltaic Series from an expanded Middle Deltaic Series : the wedging Millepore Series should be relegated to a less important role in the Middle Deltaic Series : and for convenience of reference, in localities where the Millepore Series is developed, the lower part of the Middle Deltaic Series may be termed the Sycarham Sub-Series and the upper part the Gristhorpe Sub-Series, each from localities near which the relevant beds are well exposed.

The changes may be summarized as follows, with revised maximum thicknesses from unpublished work by Dr. M. Black and the writer :—

Fox-Strangways's Terminology	Revised Terminology
Upper Estuarine Series, *c.* 200 ft.	Upper Deltaic Series, *c.* 200 ft.
Grey Limestone Series, 27 ft. to 104 ft.	Grey Limestone Series, 27 ft. to 104 ft.
Middle Estuarine Series, 100 ft. to an undefinable thickness.	Gristhorpe Sub-Series
Millepore Series, 40–0 ft.	Millepore Series, 40–0 ft.
	Middle Deltaic Series, 250 ft.
Upper part of Lower Estuarine Series, 150 ft. to an undefinable thickness.	Sycarham Sub-Series
Eller Beck Bed, 4 ft. to 17 ft.	Eller Beck Bed, 4 ft. to 17 ft.
Lower part of Lower Estuarine Series, 100 ft. to 170 ft.	Lower Deltaic Series, 100 ft. to 170 ft.
Dogger 0 ft. to 40 ft.	Dogger 0 ft. to 40 ft.

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CORRESPONDENCE

INDEX FORAMINIFERA OF THE CHALK

SIR,—Considerable research has been undertaken during the last few years, particularly by petroleum geologists, to establish zonal indices among the foraminifera of the Chalk of England, Sweden, and North Germany. The English Chalk has been studied by E. Williams-Mitchell and the Swedish by Dr. F. Brotzen, while at least six workers, Altaner, Bettenstaedt, Hiltermann, Olbertz, Wedekind, and Wicher, have made valuable contributions towards this subject in North Germany. The results of all these studies are now available in published form.

The Anglo-Iranian Oil Company, London, have received from Dr. O. Heermann, of the Deutsche Vacuum Oil Company, the gift of a topotype set of some of the material from borings at Cuxhaven and Siegfried, consisting of named and mounted index species of each zone from the Turonian to the Maestrichtian.

In order that this material may be available to students the Company have decided to present it to the British Museum (Natural History), where Mr. C. D. Ovey is gradually building up a collection of Mesozoic and Tertiary material, his ideal being to accumulate as complete a stratigraphical sequence as possible, solely for the purpose of studying the microfauna zonally and biologically. Both from this aspect and from the fact that many important type collections, including F. Chapman's and Williams-Mitchell's Chalk specimens are preserved there, the Cuxhaven and Siegfried material is obviously an enhancement.

A. G. DAVIS.

ANGLO-IRANIAN OIL COMPANY.
10th November, 1948.

THE TERM " MAGMA-TYPE "

SIR,—In their recent paper " On Magma-Types and their Nomenclature " (*Geol. Mag.*, 1948, p. 349) Mr. M. K. and Dr. A. K. Wells seem to be straining at a couple of inoffensive gnats whilst swallowing with relish a particularly monstrous camel. I am grateful to my two friends for providing me with a suitable opportunity for making a protest—long overdue—against the use and misuse of the term " magma-type ". Far too many petrologists have fallen into the habit of speaking of " magma-types ", or even of " magmas ", when they simply mean rocks. Scientific jargon, appropriate to the circles in which it is understood, cannot be altogether avoided, but this particular example is so definitely unscientific and mischievous that it has become a positive danger.

Defined objectively, a so-called " magma-type " is the mean of a number of chemical analyses of rocks (of igneous or supposedly igneous origin) so similar in composition that the deviation of each constituent from its mean

value is small. By a natural extension of associative meaning the term is commonly applied to any member of a class of rocks so characterized. The term itself, however, is a complete misnomer, because it inevitably carries with it the implication (*a*) that the rocks concerned have crystallized either from a common magma or from magmas of closely similar composition, and (*b*) that the composition of the parental magma or magmas corresponds approximately to that of the rocks from which the type is abstracted. How serious the resulting confusion of thought can become is illustrated on p. 349 of the paper under consideration, where the authors state that a " magma-type " " was meant to be only a little different from a ' rock magma ' ".

The real conception behind the term is one of similar composition and, in itself, it has not necessarily anything to do with magmas. In a word, a " magma-type " is not a type of magma ; it is a statistical concept. But composition alone rarely serves to discriminate between different modes of origin. Yet the term implies by its verbal tyranny that the mode of origin of the class of rocks concerned is already known, and that it is indisputably magmatic. Recognition of the real problems of petrogenesis thus tends to be inhibited by the hypnotic spell of an unduly generalized hypothesis for which genuine supporting evidence can be found in only a few rather obvious cases. The authors of the Mull Memoir were admittedly dealing for the most part with one of these more obvious cases, but this excuse cannot be made for others—I am thinking especially of Niggli and Billings—who have made the term a real menace to understanding and progress by extravagantly applying it to hosts of classes of rocks for which a magmatic origin has never been demonstrated.

Another example of a term which embodies a hypothesis as if it were an established fact is " Comagmatic ". Judd's " Petrographic Province " is a straightforward descriptive term that raises a most intriguing problem without presuming to prejudge the issue. Washington's " Comagmatic Region " hides the problem by implying a hypothetical solution in advance. The potash-rich volcanic rocks adjoining Ruwenzori in S.W. Uganda constitute a highly individualized petrographic province, but I have so far been unable to demonstrate that they are " comagmatic ". I mention this case because I cannot agree that the rocks concerned illustrate what Wells and Wells (p. 350) call a good example of a " magma-type ". The remarkable geochemical peculiarities of the rocks point to a high degree of consanguinity,[1] but their complex heredity has been so much modified by the effects of environment that no satisfactory genealogy can, as yet, be disentangled.

Petrological terms, both in form and definition, should as far as possible be purely descriptive and free from hypothetical petrogenetic implications. I feel very strongly that of all the many terms that fail in this respect " magma-type " and " comagmatic " are amongst the most unwarranted and the most dangerously misleading. In place of " magma-type " an objective term such as " composition-type " would adequately convey all that is needed.

As to the " gnats " of my opening sentence, I have not found in practice that the terms " olivine-basalt " and " tholeiitic " give rise to any ambiguities when used in their proper context. The proposed alternatives, however, fail to suggest—to me, at any rate—the right associations. " Simatic " suggests rocks of unknown, but probably ultrabasic composition, and is therefore too broad and ambiguous for a " type " name. " Sub-sialic " embodies a hypothesis ; " sub," moreover, suggests olivine to followers of Shand's nomenclature, whilst " sialic " distracts attention from the idea of basaltic composition ; the term is therefore inappropriate.

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15th December, 1948.

[1] It should be pointed out that this term was not coined by Harker, as stated on p. 355, but was first adopted in a petrogenetic sense by Iddings (see Harker's *Natural History of Igneous Rocks*, p. 89).

ON THE SO-CALLED METAMORPHISM OF THE TRIAS IN THE ALPS

SIR,—Many readers must have welcomed O. T. Jones's article under the above title in the *Geological Magazine*, 1948, p. 333. It recalls metasomatic effects of weathering which concern us all, whether our interest be general or particular, in which latter case it may be focused on such matters as soil or laterite, including bauxite, or the leaching and secondary enrichment of metalliferous ores. I could not help being reminded of my own "Subterranean Penetration of a Desert Climate", published in your pages in 1926; and even more of J. E. Richey's account in the Geological Survey Memoir on Ardnamurchan (1930, p. 35) of phenomena associated with Triassic cornstones: "These chemically-formed limestones, deposited from solution, are at some localities found at the base of the Trias, and in this position they are seen to have permeated and partly replaced the underlying quartzose and felspathic schistose rocks in an intricate manner. The lime-bearing solutions have attacked the schists more especially along their bedding-planes, so that cornstone is found interleaving with these much more ancient rocks." Richey then points out that other Triassic examples of the same phenomenon had been described by myself in 1925 from Inch Kenneth, off Mull, and by Albert Heim in 1920, from an Alpine locality—he might also have added by Clough in 1910 from Skye, in the Geological Survey Memoir on Glenelg, p. 91. A more recently discovered locality has been described by me from Rhum, in a *Quarterly Journal* paper, 1945 (for 1944), p. 175. Partial replacement of schist by limestone at the base of a cornstone (here of Upper Old Red Sandstone or Lower Carboniferous date) is also capitally exposed at Loch Ranza in Arran. The locality is famous because it furnished James Hutton in 1785 with an example of angular unconformity. Hutton's description in his third volume of *The Theory of the Earth*, not published till 1899, is very restrained in regard to the metasomatic phenomena. The rocks above and below the unconformity are, he says, "somewhat confused at the immediate junction."

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EDINBURGH.

18th December, 1948.

STUDIES IN THE MONA COMPLEX—THE BASE OF THE BEDDED SUCCESSION

SIR,—In the *Anglesey Memoir* (p. 168), an opinion was expressed, which was proven decisively in 1923 [1]; that between the Bedded Succession and the Gneisses there must be an unconformity, and of the first magnitude. Yet, on p. 169, I add "but this unconformity has never been found, and within the limits of Anglesey, has probably been cut out everywhere by thrusting". Is that, however, probable? In our chapter on the Succession we traced a number of horizons which, if cut out locally, did escape at other places. Why should this one never escape? How did I come by such an opinion? I think it was that really I was expecting a basal conglomerate, with boulders of the gneisses, and never finding such a bed, supposed that I had not reached the base. There was a still stronger reason. When I wrote that sentence, although (see table on p. 164, *Anglesey Memoir*) I had come to realize that the Fydlyn Beds were the lowest *known* member of the Bedded Succession, they had not been recognized to the north of the Carmel Head thrust plane. Not long afterwards they were, as shown in my paper of 1923. And the matter

[1] *Quart. Journ. Geol. Soc.*, lxxix, 334–351.

of importance is that at Mynachdy they are adjacent to gneisses, with no room for anything between. The natural inference would have been that this is their true stratigraphical base and that they rest upon the Gneisses.

Still, there is no conglomerate. Why ? Because the Fydlyn Beds are volcanic, mainly rhyolitic dust, and the base of such an accumulation must differ in important respects from a sedimentary base. Deposition, in such a case, was not preceded by erosion. And without erosion there would be no conglomerate.

From its uniformity and its very wide extension, this dust probably was showered not from a few major cones, but from a crowd of little vents, like the Mexican " hornitos " of two centuries ago. Which leads us to a further point. For the hornitos were upon land and the Fydlyn Beds, unlike so many of our old volcanic rocks, unlike their successors the Gwna spilites, do not appear to have been marine.[1] Further still, the Gneisses, under long continued terrestrial conditions, would be deeply decomposed, as are the granites of southern Cornwall. When the hornitic explosions began, this friable product of decay would not break up into blocks : it would disintegrate throughout, and blow abroad into the air, would mingle intimately with the rhyolitic dust. Thus two formations, parted really by a long interval of time, would seem to graduate into each other, so that a very great unconformity would be effectively concealed.

Connected with this is another feature : their thickness is most variable and on an enormous scale. In the Aethwy Region, where they are in the condition of mica-schist, they must be 3,000–4,000 feet, whereas at Mynachdy they can be hardly as much as 100 feet. If they were showered upon mountainous land this becomes intelligible : they could thin away rapidly from several thousand feet to nothing. Now we do know of a land, also sculptured out of gneisses, and apparently of like antiquity, which is visibly mountainous . . . the famous land of the Lewisian. We seem, in the present case, not by sight but by indirect evidence, to obtain a glimpse, if dimly, of a somewhat similar land beneath the base of the Bedded Succession.

EDWARD GREENLY.

AETHWY RIDGE,
BANGOR.

August, 1948.

REVIEWS

ERUPTIVE ROCKS. By S. JAMES SHAND. Third edition, 1947. Thomas Murby and Co., 40 Museum Street, W.C. 1. xvi + 488, 51 figs. and 4 Plates ; 30*s*.

The third edition of this well-known and stimulating work is a great improvement on its two predecessors. The previous material has been brought up to date and three new chapters on late-magmatic and post-magmatic reactions, the genesis of pegmatite, and eruptive rocks and ore deposits have been added. Moreover, the book has now been divided into two, with the rock descriptions forming a separate Part II. This is a textbook which should be in the hands of every advanced student of petrology.

[1] On Fydlyn beach there are some strips of grey phyllite which have a sedimentary aspect. But they are of trifling thickness, a few inches at the most. May we venture a suggestion that they were deposited in pools, like those of St. Vincent, in 1902, described by Anderson and Flett ?

THE STUDY OF ROCKS. By S. J. SHAND. Second edition, 1947. Thomas Murby and Co., London. xi + 236 ; 10*s.* 6*d.*

A revised and enlarged edition of this useful little introduction to the study of rocks. It is a pity that room could not be found for at least a few text-figures or plates to illustrate some of the rock types described.

S. R. N.

GEOLOGY OF THE COUNTRY AROUND WEYMOUTH, SWANAGE, CORFE, AND LULWORTH. By W. J. ARKELL. Memoirs of the Geological Survey of Great Britain, 1947. Price 17*s.* 6*d.*

It is nearly a century since the publication of the first Survey map of this area, already classical from the work of Fitton, Clarke, Fisher, and others ; it is half a century since Strahan's revised mapping and the publication of his Purbeck and Weymouth Memoir. Both fifty-year intervals were marked by great advances in geological ideas, particularly in tectonics. Strahan was necessarily influenced by Lapworth's recent classical work in the Highlands and its development by Peach and Horne, and Professor Judd's comment made to this reviewer was : " Every strike-fault is called a thrust nowadays." The last fifty years has been marked by great progress in zonal stratigraphy and refinement in palaeontology, as well as by further advances in tectonics, while many new facts have been found by deep borings in the district. At the same time some old controversies have been practically forgotten, such as the question whether the Purbeck beds were Jurassic or Cretaceous, to which Strahan devoted five pages ; while Judd's blunder over the tumbled sequence at Punfield now needs only very brief mention.

All the stratigraphical chapters in this new memoir show the care and thoroughness that we expect from Dr. Arkell, though the only really big novelty, as compared with Strahan, is the recognition of the Bembridge Limestone fauna on Creechbarrow.

A point of special interest to the reviewer is the inference from the *Cassiope* fauna of Punfield that " a direct marine connection with Spain, down the Channel, is indicated " (p. 169). This agrees with the restriction to Wiltshire, in the Aptian, of the Tethyan genus *Toucasia*, and to Devonshire, in the Albian, of *Orbitolina*.

The tectonic chapter is of great interest, in view of the complexity of structure, particularly along the base of the Chalk scarp. The Oxford Clay " dyke " in the Upwey railway-cutting, and the Cornbrash of Bincombe village are century-old puzzles, to which must now be added the Forest Marble in the brook near Sutton Poyntz waterworks (discovered by a Royal School of Mines mapping class twenty years ago, but never followed up until rediscovered by Dr. Arkell), and the Oxford Clay and Cornbrash at the foot of White Horse Hill, found during Kent's oil-prospecting. These four areas alternate with others in which Portland and Purbeck come immediately under the Upper Cretaceous, while borings at Sutton Poyntz (pp. 266–271) show these two types of sequence superposed. Dr. Arkell's explanation of these anomalies is based on the interaction of intra-Cretaceous and Tertiary earth-movements, each followed by great denudation, the earlier being post-Wealden, pre-mid-Albian.

Pleistocene history and the development of topography occupy twice the space given to them in Strahan's memoir.

The improvement in the illustrations and general get-up, as compared with the old memoir, is revolutionary. The Survey and Dr. Arkell are both to be congratulated on a very fine production, regrettably delayed for eight years by the war.

A. M. D.

SYMPOSIUM OF INFORMATION RELATIVE TO USES OF AERIAL PHOTOGRAPHS BY GEOLOGISTS. Compiled by Professor H. T. U. SMITH. *Photogrammetric Engineering*, vol. xiii, pp. 531–628, 1947.

Air photography is now well established as a valuable instrument of research in geology and geography. To the cartographer it is an indispensable aid to the mapping of unknown or ill-explored areas, particularly if they be desert or difficult of access, while to the geologist it is of special interest not only in recording surface features like rivers and rock-formations, but also, when conditions are suitable, in revealing underground structure. The wide range of interests involved is apparent from the diversity of papers offered at this symposium. Several authors write about the use of air photographs, both vertical and oblique views, for geological mapping. Two text-figures illustrating the geology of an area under forest, as determined by ground survey and as interpreted from air photographs, make an interesting comparison. The correspondence is remarkable, but without the actual photographs in question it is impossible to judge the skill needed for interpretation ; so much detail is lost in reproducing air photographs as half-tones. The extent to which solid geology may be disclosed by air photography depends very largely on the nature of the earth's surface, and the occurrence of masking soil and vegetation. When contrasted rock types are present, dense vegetation may disclose outcrops by differential growth. In Britain the structural uses described in these papers are hardly possible, and the real value of the air photograph is as a base for field-mapping.

An account of the mapping of an area in Alaska from photographs taken by the trimetrogon process shows how under suitable conditions reconnaissance geological maps can be made of quite extensive districts with a minimum of flying. These papers, however, emphasize very rightly the need for familiarity with the ground, and for photographic evidence to be checked in the field if reliable maps are to be made. Air photography can disclose geological structures in comprehensive view, and can guide us to a particular feature, but the next stage in mapping will always be with the ground surveyor who can make much more detailed observations than the airman.

Other papers deal with the use of air photographs in recording and disclosing surface features, whether varieties of soils or aspects of physical geology. This is a field in which oblique photographs are specially valuable. Many landscape features can readily be recorded in air photographs in comprehensive views that can never be obtained at close quarters. Coastal topography, river-systems, and glacial features are particularly susceptible to this treatment, and a collection of such views would be of great value to geomorphologists. The importance of these photographs for teaching is recognized in other sections of the symposium, and some of the remarkable photographs of physical features which are reproduced speak for themselves.

J. K. ST. J.

GEOLOGICAL EXPLORATIONS IN THE ISLAND OF CELEBES. By H. A. BROUWER, W. P. DE ROEVER, and C. G. EGELER. pp. 346, with figures, 18 plates, and maps. Amsterdam : North Holland Publishing Company, 1947. Price f. 27·50.

This volume sets forth the results of a geological exploration in Celebes under the leadership of Dr. H. A. Brouwer. It consists of three separate memoirs : a summary of the results by the leader, 64 pages, and two long descriptions of the metamorphic rocks of different areas by Messrs. W. P. de Roever and C. G. Egeler respectively.

Celebes is surely the queerest shaped large island in the world : and it is a large island, nearly 700 miles from south-west to north-east. It was at one time thought that its structure differed considerably from that of the Malayan region generally, but this seems not to be so. In any case, however, the run of the fold lines in this region must be very complicated, as shown by a general map, which differs much from the apparent simplicity of the

outer Sumatra–Java–Timor arc. And the neighbouring island of Halmahera is very like Celebes on a smaller scale. The shape of the island makes it very difficult to discuss its geology without a map; since, for example, the "northern" peninsula runs due east and west for over 200 miles. This book deals mainly with the central area where the four peninsulas run together in a sort of wasp-waist only about 50 miles across from north to south. Across this waist runs an important structure, a crush-zone, here called the Median Line, and there are important differences in the geology on either side of this line. On the west plutonics of a granodiorite facies and acid volcanics are abundant, while on the east the intrusions are mostly ultrabasic and basic, and metamorphic rocks are not very common. To the west, however, metamorphism is strongly developed, especially in a facies characterized by glaucophane. The age of the metamorphic series is unknown, and there is no positive evidence for the existence of Precambrian or Lower Palaeozoic rocks. Certain Palaeozoic fossils formerly recorded are now believed to have come from a Chinese chemist's shop.

The oldest rocks to which an age can be more or less definitely assigned are certain bituminous limestones and shales with *Productus* and so on, which may be Permo-carboniferous. To the reviewer this suggests a possible relation to the black-banded limestones and black shales of the Raub System of the Malay Peninsula. The presence of Trias is well-established and Dr. Brouwer thinks the Jurassic-Cretaceous sequence may be complete. There is evidence of much disturbance in the Tertiary and the granodioritic facies in both its intrusive and eruptive phases is Tertiary, and this is continued up to the present by more or less active volcanoes, mostly dacitic. In some places reef-limestones have been elevated as much as 2,000 metres.

The structure of the island is obviously very complicated, though not much is definitely known about it, no doubt owing to the usual difficulties of field work in a humid tropical climate. There are probably recumbent folds (nappes) and klippen, with much faulting and some obvious rift valleys. The theories for the origin of these last are discussed. Among other puzzling features it is found that some lake-basins descend well below sea-level, in spite of the raised reefs.

The two petrological memoirs consist of elaborate descriptions of the two facies of metamorphic rocks, one of which contains several peculiar minerals. For purely geological reasons it is believed that the two facies are of different ages, though what these ages may be there is as yet nothing to show. It is clear that there is still much of interest to be discovered in the geology of Celebes. It is important to realize that in the Dutch East Indies there is evidence of acid plutonic intrusions in the late Tertiary, probably as late as the Pliocene. R. H. R.

THE GEOLOGY OF UBEKENDT EJLAND, WEST GREENLAND, PART I. By H. J. DREVER and P. M. GAME. pp. 34, with 8 plates and 10 figs. Meddelelser om Grønland. Vol. 134, No. 8. Copenhagen, 1948. Price Kr. 2.50.

This is a preliminary account of the results of two expeditions to West Greenland from Cambridge and St. Andrews in 1938 and 1939. The island, which lies opposite to Upernivik, is about 20 miles by 14, and consists of a great variety of igneous rocks. The earliest phase was mainly picritic flood basalts, of enormous but unknown thickness, the base not being seen. They dip generally S.W. at 20°–25°. This was followed by a period of central eruption, including olivine-free basalt, rhyolite, and trachyte, followed finally by an explosive phase. There are also gabbro, granite, microgranite, and felsite, as well as breccias, tuffs, and dykes, often acid-basic composites. The early eruptions seem to have been of fissure type as indicated by tholeiite dykes. The whole thing shows a certain affinity to the Isle of Mull, but it is obvious that much more work, which will be awaited with interest, will be required in the island and on the abundant material brought home by the expeditions. R. H. R.

MALAYAN UNION. REPORT OF THE GEOLOGICAL SURVEY DEPARTMENT FOR THE YEAR 1947. By H. SERVICE. pp. 39, with 2 maps, one coloured. Kuala Lumpur: Government Press, 1948. Price 3*s.* 6*d.*

In the absence of the Director on home leave, this annual Report is written by the Acting Director. It records a general progress of recovery from the devastation caused by the Japanese invasion: in particular the chemical laboratory seems to have been more or less restored to normal conditions. Mineral production in the country during 1947 was increased though new ventures are still considerably handicapped by a general loss of prospecting records. Much attention has also been paid to the possible development of hydro-electric plants. But to geologists in general the most interesting feature of the Report is the record of a large fauna from near Kuantan in Pahang. The fossils have been named and described at the British Museum (Natural History), and are found to be of Viséan age. They include some trilobites, assigned to *Phillipsia*, the first fossils of this kind to be found in the country. The rest are mostly brachiopods, with a few mollusca and corals.

R. H. R.

EMANUEL KAYSER'S ABRISS DER GEOLOGIE. Zweiter Bd., Historische Geologie. 6th edition, completely revised by R. BRINKMANN. pp. vii + 355, with 64 figures and 58 text-plates. Stuttgart: Ferdinand Enke, 1948. Price 25 Marks (geb., 27 Mk.)

This must be one of the first geological textbooks to come out of post-war Germany; the paper is rather poor, as usual throughout Europe to-day, but the typography and general style seem well up to pre-war standard of the Stuttgart and Berlin publishers, and the book has much to commend it for any student to whom the German language presents no difficulties.

The standard seems to be about that of our Pass Degree, but the field covered is considerably larger than that of the ordinary pass degree of this country since the survey is world-wide; moreover, it is remarkably well balanced, though the emphasis is naturally upon Europe and upon Germany in particular. Details of stratigraphical successions are left entirely to correlation tables, and find no place in the text, which is accordingly far more readable than the majority of stratigraphical textbooks. The plan adopted for each system is a brief introduction and definition, followed by a general account of the principal areas of development (often illustrated by palaeogeographic maps); then comes a fairly full discussion of the fauna and flora, well illustrated in a manner reminiscent of the "Stanford Atlas" plates, though fuller and much more up-to-date. Whilst the Cambrian has 12 figures on one "text-plate", the Cretaceous has 82 figures on 11 plates. The account of each system concludes with a general discussion of climate, palaeogeography, crustal movement, etc., and is illustrated by a world palaeogeographic map. One cause for regret is that, while a vast amount of literature has obviously been drawn upon in the compilation of this work, the references cited at the end of each chapter are extraordinarily few and those few most curiously chosen.

O. M. B. B.

STRUCTURAL GEOLOGY OF CANADIAN ORE DEPOSITS—A SYMPOSIUM. 8vo. pp. x + 948. Canadian Institute of Mining and Metallurgy, 1948. Price $10.00.

This splendid volume, which fittingly commemorates the fiftieth anniversary of the founding of the Canadian Institute of Mining and Metallurgy, assembles a wealth of information concerning structural features that have influenced

the localization and form of ore-bodies in Canadian metalliferous areas. Whilst the nature of the ore fluid, its composition, and mode of transportation are all problems of intriguing interest, of greater significance in the actual search for ore are the recognition of mineralogical and lithological guides, and especially of structural controls that so largely determine the locus of ore deposition. Fissures, joints, faults, shears, brecciation zones, and kindred fractures not only afford requisite channel-ways for the entry of metallizing solutions, but also serve as sites for the precipitation of ore minerals and as the starting-places for the progressive evolution of replacement ore-bodies. Within recent years growing emphasis has been laid on the role of geological structure in the emplacement of epigenetic mineral deposits, and it becomes increasingly clear that a proper appreciation of the relevant structural factors in a mineralized district can aid considerably in planning the further development of operating mines and in the exploration for virgin ore-bodies.

An avowed object of this volume is a " stock-taking " of existing information correlating structure and ore deposition within a wide range of individual mines and districts throughout Canada. It is a stimulating collection of papers, replete with local detail and structural analyses, which merits the careful study of all geologists and mining engineers interested in the discovery and development of metalliferous deposits.

The Symposium gathers together in 132 separate papers the work of more than 120 contributors, and is copiously illustrated with admirably neat line drawings and many half-tones of photographs. Most of the papers on individual mines have been written by the mine geologists themselves, the general papers describing more extensive tracts being contributed mainly by government geologists. The volume opens with valuable synoptic papers by Lang, Gill, and Alcock, summarizing the general geology, mineralization, and structural controls within the three most productive provinces of Canada, namely the Cordilleran, Canadian Shield, and Appalachian regions. These are followed by descriptions of the principal structural controls within particular mining fields, such as those of Yellowknife-Great Bear Lake, Porcupine, Sudbury, and Nova Scotia, supplemented by a long series of articles on structures related to mineralization at individual mines. In many cases the disposition of lodes and vein-patterns agrees closely with the theoretical directions of shear and tension fracturing indicated by appropriately oriented conventional strain ellipsoids. At numerous mines a clear distinction is recognized between favourable and unfavourable rocks, and commonly an intimate relationship can be discerned between mineralization and rock competence, fracture deflections, folding, and structural barriers that have impeded the flow of metallizing fluids.

Readers in Britain will probably find most interest in the regional papers and in the up-to-date views on such famous mining camps as Sullivan, B.C. (lead-zinc), Eldorado (uranium), Porcupine and Kirkland Lake (gold), and Sudbury (nickel-copper-platinum). Yates, in a masterly description of the Sudbury district, indicates how untenable is the classical hypothesis of Coleman and others which attributed the localization of the nickel sulphide deposits at the base of a norite sill to a process of gravitational segregation *in situ*, and himself emphasizes the role of later intrusions of quartz diorite and breccias in controlling the locus of ore deposition. It is interesting to note that whilst Yates asserts that the position and shape of the norite was governed by its intrusion into a large, pre-existing syncline, Cooke concludes that the norite must have been injected, and consolidated, before the Sudbury basin began to develop. In the Porcupine district the locus of gold-ore deposition was chiefly determined by the degree of deformation, especially of shearing, that was produced by folding. Here, as in so many other areas, structure and variations in rock competence seem to have been of greater significance in controlling the sites and form of ore-bodies than any possible genetic relationship between mineralization and near-by igneous intrusions. The importance of neighbouring intrusive stocks and dykes lay largely in their influence on the distribution of later fracture zones which

facilitated the entry of ore-bearing solutions, and often there is no direct consanguinity between the ore-bodies and accompanying intrusive rocks.

This outstanding book, summarizing the views of Canadian geologists on the structural control of ore deposition, will be a welcome guide and stimulus to all engaged in the search for ore, and is confidently recommended to everyone interested in the problems of ore localization. Thanks are due to the Symposium Committee, under the Chairmanship of M. E. Wilson, for assembling a feast of detailed and general information in such an attractive and worth-while volume.

D. W.

THE COAST OF NORTHEAST GREENLAND. By LOUISE A. BOYD. x + 339, with 194 figures and separate case with 12 folding maps and panoramas; American Geographical Society, special publication No. 30. 1948.

Here are the collected results of expeditions to N.E. Greenland in 1937 and 1938, publication of which was suspended during the war for security reasons. A Norwegian vessel, *Veslekari*, was chartered, and the trips included visits to West Spitsbergen and Jan Mayen. Miss Boyd, in addition to financing and leading the expeditions, used a variety of equipment to obtain a large number of excellent photographs. Apart from providing a pictorial record of much of the coastline visited, some photographs have been used subsequently for the construction of maps by employing simple techniques described by F. W. Buhler and J. M. LeRoy. One may well wonder whether the energy of the six porters (p. 87) could not have been better employed in establishing phototheodolite stations.

The main work of the expeditions was hydrographical. LeRoy describes the echo sounding equipment used both on the *Veslekari* and on a motor-boat. The results are shown on a series of charts. One new feature discovered was Louise A. Boyd Bank, approximately 73° N., 3° E., where there is a rise from an average depth of 2,500 to 600 metres.

R. F. Flint and A. L. Washburn were the geologists on the 1937 expedition and describe in detail many glacial features of the regions, but any general conclusions must await more detailed work. In 1938 a much smaller geological programme was possible. One interesting feature was the description by F. E. Bronner of an apparently post-glacial laterite (p. 223) derived from metamorphosed basic intrusions and sediments on a newly described island 76° 41′ N., 19° 55′ W., on the Orientering group. Botanical collections and current, tide, and magnetic observations were also made. The fine quality of the publication has certainly displayed the expeditions' achievements to the best advantage.

W. B. H.

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